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MESOZOIC STRATIGRAPHY OF THE FOOTHILLS REGION OF ALBERTA

H. KUNST

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MESOZOIC STRATIGRAPHY

of the

FOOTHILLS REGION of ALBERTA

by

Henry Kunst, B.Sc.

Department of Geology,

UNIVERSITY of ALBERTA

A Thesis
Submitted to the University of Alberta
in partial fulfilment of the
requirements for the degree
of
MASTER of SCIENCE

Edmonton, Alberta. April, 1941.

Thesis
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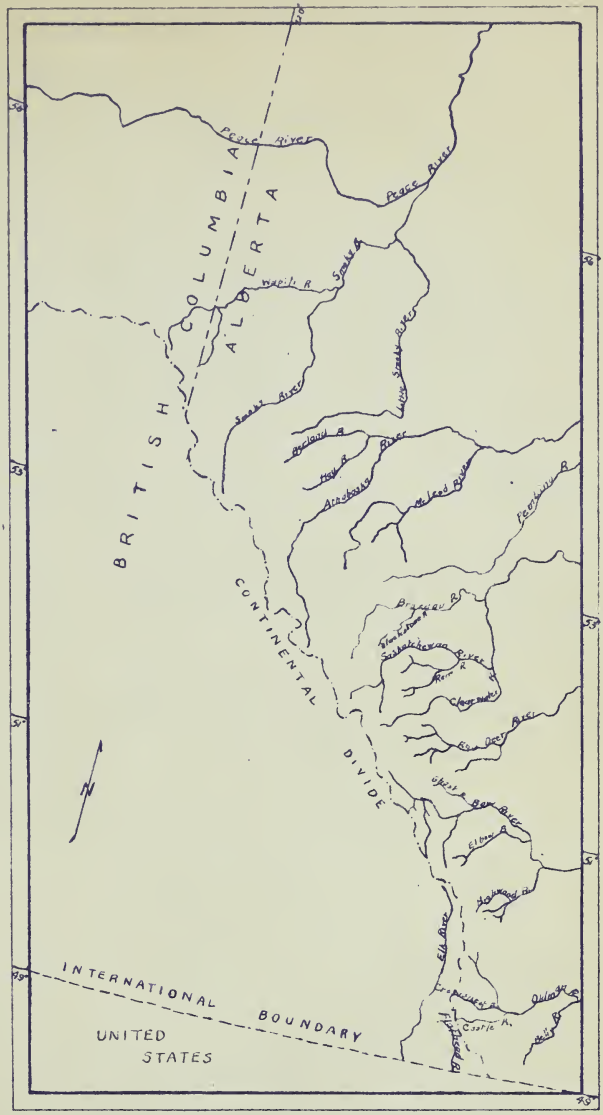

MAP OF FOOTHILLS AND MOUNTAINS OF ALBERTA

MESOZOIC STRATIGRAPHY OF THE FOOTHILLS REGION OF ALBERTA

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CHAPTER I

INTRODUCTION

Introductory Statement

This thesis represents a resume of the literature on the Mesozoic stratigraphy of the foothills region of Alberta and such contiguous areas as are pertinent to a clearer understanding of the discussion. The writer is not acquainted with the field relationships of the formations and has, therefore, been forced to rely solely on the findings of others. The extent of the bibliography shows that much has been done, but there remains, nevertheless, a host of problems which require solution.

Location and Extent of Area

The area to be considered in this discussion of the Mesozoic stratigraphy has been limited by the thesis topic, to that portion of western Alberta constituting the foothills from the 49th parallel northwestward to the vicinity of the Peace river - that is, northwestward to just beyond the 56th parallel. It has been found necessary, however, in order to obtain a clearer understanding of the formations, to consider contiguous areas comprising the Rocky mountain region, and such areas of British Columbia which have been found pertinent to the discussion.

Instances of such regions are part of the Crowsnest and Fernie districts of southeastern British Columbia and the Peace river canyon area of the northeastern section of that province.

Scope of the Thesis and Method of Treatment

This dissertation reviews the stratigraphy of the Mesozoic formations within the area as delimited. Each formation is treated as a separate entity. Previous work, lithology, distribution, thickness, faunal and floral assemblages, correlations within the area, and the relationship of the formation to overlying and underlying strata is all considered in the present discussion. No attempt is made to study the structure and structural implications of the area.

The procedure adopted for each formation has been to review briefly the investigations which have been made concerning it, and to point out general relationships. The type locality and section has then been discussed, followed by a consideration of the areal characteristics and variations of the formation from south to north. In conclusion the fossil fauna and flora of the formation have been considered.

Previous Work

No study of this nature for the area under consideration has been attempted previously. In the main, studies have been of a local nature with no regard for regional relationships. However,

two papers by Dr. P. S. Warren, one on the Fernie shale (163), and one on the Kootenay-Blairmore succession (165), have been of this regional type. Throughout the text of the thesis notation has been made of the pertinent references.

Acknowledgments

The writer wishes to express his indebtedness to the members of the Department of Geology, University of Alberta, who have made possible this thesis. To Dr. J. A. Allan for his pertinent suggestions and kindly advice; to Dr. P. S. Warren under whose direction this work has been carried on, who has devoted so generously of his time and knowledge of the stratigraphy of the area under review, and who has permitted access to his personal library; to Dr. R. L. Rutherford for his constructive criticisms and the use of certain publications which otherwise would have been unavailable; to these men, who have given so liberally of their time, their knowledge and their advice in the reading of the manuscript, does the writer extend his sincere gratitude.

Summary

In this thesis an attempt has been made to provide a summary of the stratigraphy of the Mesozoic formations in the foothills region of Alberta, and such contiguous areas as are deemed relevant to a clearer conception of the problem under review. The location and extent of the area, the scope of the thesis, the method of treatment, generalized ~~columnar~~ sections for the

region and correlation of formations within the area, have all received attention. Stratigraphical geology constitutes the main body of the thesis; a brief summary of this follows.

Spray River Formation - Lower Triassic

The Spray River, composed of dark grey dolomites and limestones intimately intermixed with shale and some sandstone, is developed to a maximum known thickness of 3,000 feet in the mountains, but exhibits a rapid thinning towards the foothills to the east where its development is extremely limited. It is considered to lie for the most part on the Rocky Mountain quartzite of Pennsylvanian age. The affinities of the fauna are with the Lower Triassic of the western States.

Schooler Creek Formation - Upper Triassic

The Schooler Creek, of Upper Triassic age, constitutes a marine sequence of sandstones, siltstones, and limestones developed to a thickness of over 2,500 feet. This formation, as far as is known, does not extend south beyond Jasper Park and represents a deposit of a northern sea. The Jurassic Pine River shales overlie the Schooler Creek, and as yet the lower contact has not been observed.

Fernie Shale - Jurassic

The Fernie is represented in the area by about 1,000 feet of grey to black shale. Although a complete succession of faunas has not been found, faunas Sinemurian to Argovian in age

have been reported. In the mountains the Fernie overlies the Spray River, but in the outer foothills in some parts it rests unconformably on the Carboniferous Rundle limestone. The Fernie grades upwards through sandy beds into the Kootenay.

Kootenay Formation - Lower Cretaceous

The Kootenay, a continental succession of alternate dark grey-colored shales and drab, buff-colored sandstone, with coal seams, is developed to an average thickness of 300± feet in the foothills region, with a thickening to the west. The age from floral evidence is Barremian of Lower Cretaceous time.

Blairmore Formation - Lower and Upper Cretaceous

A marked resemblance exists between the Kootenay and Blairmore, but the latter is usually coarser in texture and more of a greenish color. A strong conglomerate marks the base of the formation and other conglomerates occur higher up in the formation. A pronounced thickening of the formation to the west and to the north exists. The thickness of the Blairmore in the foothills varies from approximately 1,000 to 2,500 feet. An unconformity between the Kootenay and Blairmore has been observed, in some places. The Blairmore is of Lower Cretaceous (Aptian-Albian) age except for the upper 200 feet which are considered to be Upper Cretaceous (Cenomanian) in age.

Crowsnest Volcanics - Upper Cretaceous

The Crowsnest volcanics, consisting of tuffs, agglomerates and flow rocks, are limited in their areal distribution to the

Crowsnest pass area and represent the only known occurrence of igneous rocks in the foothills region. They overlie immediately the Blairmore formation and are overlain by the Alberta shale.

Alberta Shale - Upper Cretaceous

The Alberta shale, a marine sequence of Colorado and Lower Montana age lying between two series of freshwater deposits, is composed of dark grey to black shales divided by a sandstone bed. The formation thins from about 2,700 feet in the Turner Valley area to nearly half this amount in the vicinity of the Peace river. The Alberta shale conformably overlies the Blairmore and is conformably overlain by the uppermost Cretaceous continental beds.

Uppermost Cretaceous

The uppermost Cretaceous beds consist in the main of freshwater sandstones. In the southern foothills area, however, the marine Bearpaw provides a means of division of the continental succession into Belly River below and Edmonton above. In the foothills, continental deposition was apparently continuous into the Tertiary deposits.

CHAPTER II

GENERAL GEOLOGY

Stratigraphic Sections and Correlation Table

General Statement:

The writer has chosen the stratigraphic sections of three areas to show, in the main, the variation in the stratigraphic succession of the Mesozoic formations of the foothills region of Alberta. The Turner Valley section is based on a report of Hume (54), that of west-central Alberta on a publication of MacKay (71), and that of the Peace river area has been drawn from a number of sources (97), (100), (110), (117), (136), (147), (177).

The following correlation table of the Mesozoic succession in the foothills region of Alberta is the interpretation placed upon these strata by the writer. References to each area have been included, but the writer wishes to make it clear that these references are merely to the reports from which material has been drawn for each area, and not of any correlation which these authors may or may not have made.

STRATIGRAPHIC SECTION OF TURNER VALLEY

Age		Formation	Thickness Feet	Lithology
Upper Cretaceous	Montana	Edmonton	1,100 - 1,600	Ss. and sh., in part highly bentonitic; soft ss. with ironstones, sh., and coal in lower part; heavy bedded, harder ss. alternating with sh. in upper part
		Bearpaw	150 - 400	Shale with some ss. bands, thin coal seams and bentonite. In places glauconitic bands and pinkish ss.
		Belly River	1,600 - 1,800	Ss. alternating with green and dark shales; a thick coal seam in upper part and a thin coal seam about 20 ft. above base
	Colorado	Upper Alberta Shale	1,700 - 1,800	Sh. and sandy sh.; marine
		Cardium	30 - 40	Grey ss. and sandy sh.
		Lower Alberta Shale	800 - 900	Sh. with thin ss. bands; marine
Lower Cretaceous		Blairmore	1,050 - 1,200	Ss. and green sh.; small amounts of coal in upper part at two horizons; lower part of brown limy ss. and ls. alternating with dark sh.; at the base a cgl. and ss. known as the Dalhousie ss; other cgl'c. sandstones higher up
		Kootenay	20 - 100	Brown, hard ss. alternating with dark sh.; coal in upper part
Jurassic		Fernie	200	Brown thin-bedded ss. at top; dark to black sh. with thin, limy bands in lower part; marine formation containing phosphate material

STRATIGRAPHIC SECTION OF WEST-CENTRAL ALBERTA

Age		Formation	Thickness Feet	Lithology
Tertiary		Brazeau	11,000	Freshwater, soft, grey, cross-bedded, green- and brown-weathering ss. and greenish-grey sh. with several massive beds of cgl. composed of small chert and qtzt. pebbles; one volcanic-ash bed and several important coal horizons about 8,000 ft. above base
Upper Cretaceous	Montana	Wapiabi	1,700	Black marine sh. and thin calcareous beds, some layers of which contain large ironstone concretions
Upper Cretaceous	Colorado	Bighorn	350	Mostly marine and some freshwater beds. Alternating brown-weathering grey ss. and dark green to black sh., and lenses of chert cgl.; thin impure coal seams occur locally
Upper Cretaceous	Colorado	Blackstone	1,700	Black and green fissile marine sh. with lenses and thin beds of impure limestone and iron carbonate concretions
Lower Cretaceous		Mountain Park	400	Hard, rusty-brown-weathering coarse, cross-bedded ss. and olive-green sandy sh., and lenses of rusty-red-weathering cgl., composed largely of small black chert pebbles
Lower Cretaceous		Luscar	1,700	Soft, grey ss., interbedded with dark grey sh. and several cgl. lenses. Contains all the L. Cret. commercial coal seams of the district
Lower Cretaceous		Cadomin	35	Massive, resistant, light-colored cgl., composed of pebbles of qtzt., chert, and vein qtz. firmly cemented in a clean siliceous matrix
Lower Cretaceous		Nikanassin	1,900	Dark-grey sh., and brown-weathering grey ss. with thin impure coal seams
Jurassic		Fernie	1,300	Black marine fissile sh. and thin beds of fine-grained, buff-weathering quartzitic ss. A black chert bed and qtzt. cgl. are locally present at the base
Lower Triassic		Spray River	700	Thin-bedded, fine-grained arenaceous sh., overlain by soft, alternating buff and red ls. and grey fissile sh.

STRATIGRAPHIC SECTION OF PEACE RIVER AREA

Age	Formation		Thickness Feet	Lithology
Tertiary				
Upper Cretaceous	Wapiti		1,100+	Freshwater ss. and sh. with small coal seams
Upper Cretaceous	Smoky River		1,000-	Dark marine sh. and interbedded ss. A dark red, medium- to coarse-grained, porous ss. divides the formation into upper and lower members
Upper Cretaceous	Dunvegan		450-1,000	Medium-grained, light-colored, cross-bedded, massive ss, and thin-bedded, arenaceous sh.; grits and fine cgls. and ls. lenses occur locally; coal seams; marine
Lower Cretaceous	St. John		550-1,300	Thin-bedded, dark, hard, friable sh. with banded concretions of ironstone
Lower Cretaceous	Gates		50-80	Massive, cross-bedded ss.; marine
Lower Cretaceous	Moosebar		800±	Dark, friable sh. and thin bands and irregular concretions of clay ironstone
Lower Cretaceous	Bullhead Mountain	Gething Member	1,400±	Non-marine ss. and sh.; contains commercial coal seams; clay ironstone present
Lower Cretaceous	Bullhead Mountain	Lower Member	3,000+	Conglomerates, grits, and coarse ss. with minor amounts of medium to fine ss. and sh.
Jurassic	Pine River		600	Blue-black marine sh. with intercalated ls. and some ss.
Triassic	Schooler Creek		2,500+	Calcareous, very fine ss, calcareous siltstone, and minor amounts of shelly, crinoidal, partly oolitic, argillaceous, and arenaceous ls.; weathers purplish

CORRELATION TABLE OF MESOZOIC SUCCESSION IN FOOTHILLS REGION OF ALBERTA

European Age Equivalent	Time Division	Crowsnest Pass	Turner Valley	Bighorn Basin	Saunders Creek-Nordegg	Foothills Brazeau	Mountain Park - Cadomin	Athabaska-Smoky	Peace River
	Tertiary	?		?	?	?	?		?
Senonian: Santonian	Upper Cretaceous	Montana: Allison	Edmonton, Bearpaw, Belly River	Brazeau	Saunders	Saunders	Brazeau	?	Wapiti
Emscherian	Upper Cretaceous	Colorado: Alberta shale: Up. Alberta sh.	Alberta shale: Up. Alberta sh.	Wapiabi	Wapiabi	Wapiabi	Wapiabi	Berland River sh: Upper shale	Smoky River sh: Upper Smoky River Badheart
		Cardium	Cardium	Bighorn	Bighorn	Bighorn	Bighorn	? Upper sandstone ?	
Turonian		L. Alberta sh.	L. Alberta sh.	Blackstone	Blackstone	Blackstone	Blackstone		Kaskapau
Cenomanian		Crowsnest volcanics						?	Dunvegan
Albian	Lower Cretaceous	Upper Blairmore	Upper Blairmore	Dakota	Kootenay Group	McLeod	Mountain Park	Sunset	St. John, Gates
Aptian		Blairmore: Lower Blairmore	Blairmore: Lower Blairmore	Kootanie		Kootenay	Luscar	Kootenay	Moosebar; Bullhead Mountain: Gething
		Blairmore cgl.	Blairmore cgl.				Cadomin		?
Barremian		Kootenay	Kootenay				Nikanassin		Bullhead Mountain: Lower member
	Jurassic	Fernie	Fernie	Fernie	Fernie	Fernie	Fernie		Pine River
	Upper Triassic								Schooler Creek
	Lower Triassic	Spray River		Upper Banff sh	Upper Banff sh		Spray River		
		Ref. 123, 110, 73, 54.	Ref. 54, 110	Ref. 84	Ref. 3	Ref. 4	Ref. 71	Ref. 83	Ref. 110, 100, 97, 136, 147, 177.

CHAPTER III

STRATIGRAPHY

1. Spray River Formation - Lower Triassic

Introduction

The Spray River is the oldest Mesozoic formation occurring in the Rocky Mountains and foothills region of western Alberta. It extends northwestward from the 49th parallel to the vicinity of Jasper Park. In general it lies disconformably on the Rocky Mountain quartzite of Pennsylvanian age, and throughout most of its areal distribution is overlain by the Fernie shale of the Jurassic.

Previous Work

G. M. Dawson (183) while on the British North American Boundary Commission survey in 1875, erroneously referred the Kintla red beds, now known to be Precambrian, to the Triassic. Later he assigned a 600-foot series, south of the Crowsnest pass, composed mainly of magnesian sandstone and limestone, to a probable Triassic or Permo-Triassic age (24). The age of these beds is not known. It was R. G. McConnell (87) who, in 1887, along the main line of the Canadian Pacific Railway first studied the succession of rocks now known to be Lower Triassic in age. He

called them the Upper Banff shales and considered them to belong to the Carboniferous. In 1907 D. B. Dowling (28) working in the Cascade coal basin, referred these beds to the Permian-Triassic. On the basis of the species Monotis circularis, found on a branch of the Brazeau river, he in 1911 assigned them to the Triassic (84, p. 47). H. W. Shimer (190) in 1913, and J.A. Allan (1) in 1914, placed them in the Permian. In 1916 they were, on reliable fossil evidence, assigned to the Lower Triassic by L. M. Lambe and E. M. Kindle (58, pp. 37-38). In 1924 Kindle (55, p. 124) proposed the term Spray River formation to supersede the name Upper Banff shale. In the same year P. E. Raymond (121) found the genus Meekoceras, known to be indicative of a Lower Triassic horizon. P. S. Warren (154) in 1923 made the first detailed study of the Spray River formation in its type locality near Banff. Other writers, through whose efforts our knowledge of the formation has been enlarged, include G. S. Malloch (84), B. R. MacKay (71), E. Parejas (120) and L. Telfer (153).

Lithology, Distribution, Thickness

General Statement: The Spray River formation comprises a rather diversified group of strata including argillaceous limestones and dolomites, banded calcareous and dolomitic shales, and arenaceous shales (154, pp. 38-39). The beds weather easily and are now generally found underlying the valley floors

between some of the mountain ranges. Exposures thus are few as the beds are usually obscured by glacial drift and talus. Although many of the beds are quite massive, they are subject to rapid disintegration and often assume a shaly habit. On weathering the strata assigned to this formation may be distinguished easily even at a great distance by their dark red or brown color.

The Spray River is known to extend from the vicinity of the International Boundary northwestward to at least as far as Jasper Park. The formation is mainly confined to the mountains but it does appear in restricted localities in the foothills. G. S. Hume (47, p. 39) in 1933 stated that the Triassic outcrops only in the Rocky mountains and foothills where faulting and folding has brought it to the surface. He concluded that no Triassic is known in the foothills south of the Bow river, Jurassic strata resting directly, as far as is known, on the Palaeozoic limestones. The Spray River, however, is present at the eastern edge of the front ranges at Blairmore.

In the mountains the maximum thickness of the formation in the type locality has been placed at 3,000 feet by Dr. Warren*, but the formation thins rapidly to the east. The Spray River rests disconformably on the Rocky Mountain quartzite of Penn-

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* Personal communication.

sylvanian age (154, p. 38), and its upper contact with the Fernie shale of the Jurassic is disconformable (153, p. 572).

Banff Area - The Type Section: The type locality of the formation as given by Kindle (55, p. 124) "is the Spray River gorge, 7 miles above Banff and the adjacent exposures at the foot of Rundle Mountain". Warren (154, p. 39) has described the Spray River as follows: "The Spray River shale consists essentially of calcareous or dolomitic shales and argillaceous limestones and dolomites. The rocks are generally dark grey to black and many are finely banded. The banding is due to alternating layers of dark, argillaceous material and light grey dolomite or limestone. Such beds disintegrate easily where exposed to the weather and assume a shaly habit. Other beds of argillaceous limestone and dolomite are quite homogeneous and show no banding. They are extremely tough and very fine-grained and do not weather easily. Such beds are common in the lower part of the formation where they yield an excellent building stone". This building stone has been utilized in the construction of the Banff Springs Hotel, the Administration Building, the Banff School of Fine Arts, the Cave and Basin swimming pool, etc.

In places in the banded calcareous shales near the base of the formation beds of nodular limestone occur. Warren (154) believed the nodular character of these beds to be due to

the irregular leaching of the calcareous material from the surrounding shale. Occurring at irregular intervals throughout the formation are beds of pure, grey limestones, dolomites, and magnesian limestones of a coarser texture (154). In this area, a fine-grained textured dolomite containing chert nodules, attains a thickness of 142 feet. Another characteristic bed - a soft, light grey to yellowish limestone, in many cases porous and brecciated - occurs near the middle of the formation. Arenaceous shales are developed in some localities, but are limited in their distribution and range. In thin sections of some of the calcareous and dolomitic shales, small amounts of arenaceous material have been reported (154). Mud-cracks and rain-prints characteristic of the lower part of the formation, are also found higher up in the section. True ripple-marks seldom occur, many of the so-called ripple-marks which are so prevalent are considered merely nodular layers of limestone due to irregular leaching (154).

The following section measured by Warren (154, pp.40-41) shows the characteristic development of the Spray River formation in the type locality.

Section of Spray River Formation at the

South End of Sulphur Mountain

Character of Beds	Thickness Feet
Fault-contact with overlying Devonian rocks not observed	
Grey, very fine-grained, thick-bedded, magnesian limestone	34
Dark grey, fine-grained, laminated, dolomitic shales	39
Grey, fine-grained, thick-bedded, laminated, argillaceous dolomite	47
Dark grey, fine-grained, laminated, dolomitic shale	129
Not exposed	110
Dark grey, fine-grained, laminated, dolomitic, and calcareous shales	430
Light grey, fine-grained, thick-bedded dolomite with lenses and layers of grey chert nodules	142
Black, very fine-grained, thin-bedded dolomitic and calcareous shales, many of them laminated	535
Dark grey, fine-grained, argillaceous, magnesian limestone interspersed with beds of fine shale	73
Dark grey, very fine-grained, massive, argillaceous, magnesian limestone	8
Grey, fine-grained, magnesian limestone interspersed with beds of light grey, medium-grained limestone and light grey to buff-colored, soft, porous limestone	139
Grey, fine-grained, thin-bedded, magnesian limestone	33
Black, very fine-grained, dolomitic shale	31
Light grey, medium-grained, thin-bedded limestone	8
Grey, very fine-grained, massive dolomite	69
Dark grey, very thin-bedded, dolomitic shale	50
Dark grey, very fine-grained, thin-bedded, argillaceous, magnesian limestone	25
Dark grey, fine-grained, thick-bedded, laminated, argillaceous, magnesian limestone	82
Dark grey, fine-grained, medium-bedded, magnesian limestone. These beds are badly folded in the section	40
Soft, light grey or buff-coloured, fine-grained limestone with an occasional bed of hard fine-grained, rubbly limestone, in many cases badly brecciated, and very porous, tufa-like limestone	133

Dark grey, fine-grained, thick-bedded, argillaceous, magnesian limestone	17
Soft, dark grey, dolomitic shale	37
Light grey, medium-grained, thick-bedded, magnesian limestone	5
Dark grey, fine-grained, massive, argillaceous, magnesian limestone	61
Grey, fine-grained, thick-bedded, magnesian limestone	18
Grey, fine-grained, nodular, magnesian limestone interbedded with thin layers of fine, black shale	20
Dark grey, thin-bedded, laminated, argillaceous, magnesian limestone	54
Grey, fine-grained, thick-bedded, magnesian limestone	41
Dark grey, medium-bedded, laminated, argillaceous limestones or calcareous shales	238
Grey, fine-grained, medium-bedded, magnesian limestone with thinner argillaceous beds variously interspersed	52
Dark grey, thin-bedded, laminated, calcareous or dolomitic shales	374
Black, calcareous shales with a few beds of fine-grained, nodular, magnesian limestone	109
Black, fine-grained, laminated, calcareous shale interspersed with beds of dark grey to black, fine-grained, argillaceous limestone	64
Black, very fine-grained, dolomitic shale interspersed with beds of black, fine-grained dolomite	153
Total	3,400

Underlying formation - Rocky Mountain quartzite

This thickness of the formation has since been considered too great, Warren* now assigning a thickness of 3,000 feet to the strata of the Spray River. In the Banff area (154, p. 39) the Spray River rests disconformably on the Rocky

* Personal communication.

Mountain quartzite, and its upper boundary is marked by great thrust faults separating it from older overthrust strata. Faulting and folding are common throughout the formation.

Foothills Area: Early workers in the Crowsnest pass area including McEvoy (90), Leach (61-64), MacKenzie (77), and Rose (123), (124), (125), reported no rocks of Triassic age. In 1932 MacKay (72) assigned 350 feet of massive, brownish, sandy quartzites and thin, shaly sandstones to the Triassic, but stated that their age is doubtful as no fossils were found. They differ lithologically from the underlying quartzites, an erosional unconformity marking the contact. These strata were correlated with the Spray River formation both on their lithologic resemblance to this formation in the Banff area, and because of their stratigraphical position. MacKay stated further, however, that it is not improbable that they represent the lowermost beds of the Fernie formation, as they merge imperceptibly into the phosphatic beds which contain a lower Jurassic fauna. The beds thin rapidly to the east, and whereas they are 350 feet thick at Crowsnest, at Blairmore they have thinned to 50 feet (73, p. 30B).

In the Panther river area north of Banff the formation consists of a thin-bedded shale, and occurs both in the front ranges of the mountains and at the headwaters of the river (153).

The contact with the underlying Rocky Mountain quartzite is here disconformable.

In the Mountain Park region northwest of Nordegg, the upper beds of the Spray River formation are said to consist of white limestones (163, p. 63). At Jasper, Luscar and Pocahontas the Spray River formation was described by Telfer (153, p. 581) as a thin-bedded shale with a disconformable rusty contact with the underlying Rocky Mountain quartzite.

Allan, Warren and Rutherford (5) in their reconnaissance mainly along the motor road in the eastern ranges around Jasper, included all the Triassic rocks of the area in the Spray River formation. The formation was identified both by its lithologic character and its position in the section. In this area it consists typically of black, thin-bedded, argillaceous limestones and dolomites, and black calcareous shales with subordinate sandy beds. On weathering it generally assumes a rusty brown color and a shaly habit. As exposures along the highway are scarce, no good measurements for thickness were obtained, but the thickness probably does not exceed 300 or 400 feet. In 1934 a thickness for the formation in this area of 400 to 700 feet was reported by Allan and Rutherford (8,p.31). In this region the Spray River formation lies directly on the Rundle limestone and is overlain by the Fernie shale (5). While

the section on Folding mountain and Ashlar ridge show the lower boundary as well-exposed, nowhere was the contact with the overlying Fernie observed (5, p. 242).

Palaeontology and Correlation

In this formation fossils are, as a rule, scarce and poorly preserved, but they do occur rather abundantly in restricted layers at certain localities. It was this paucity of organic remains which led to much controversy as to the age of the Spray River formation.

In 1924 the first conclusive evidence of the Lower Triassic age of the formation was submitted. In that year the Harvard school of field geology under Raymond (121), working in the area around Banff, found the diagnostic Meekoceras gracilitatus White. This find definitely proved the Lower Triassic (Meekoceras) age of the formation. Other ammonites described at this time were Gyronites aplanatus (White) and Columbites parisianus Hyatt and Smith. The Columbites fauna is distinctive of the uppermost Lower Triassic Columbites zone of J. P. Smith (191).

Concerning the fauna in the Banff area Warren (154,p.41) stated it is largely new, but that some of the pelecypods are close to, if not identical with, some forms from the Triassic (Meekoceras) bed of the western States. In this connection he mentioned Aviculopecten parvulus Hall and Whitfield, and

Aviculopecten idahoensis Meek. Ammonites collected were too poorly preserved to admit of identification. Lingula and poorly preserved ammonites were found in the lower beds, while higher horizons yielded Aviculopecten and other pelecypods.

The species of ganoid fishes as described from this formation are as follows: Platysomus canadensis Lambe (57), Coelocanthus banffensis Lambe (58), Acrolepis laetus Lambe (58), Belonorhynchus davi Raymond (121), and Platysomus brewsteri Warren (164).

To show the age relationship of the fauna in this area to the standard of reference for the world, J. P. Smith's (191) zonal classification of the Lower Triassic is here appended.

V.	Columbites zone		
IV.	Tirolites zone		
III.	Meekoceras zone	III.c.	Anasibirites subzone
		III.b.	Owenites subzone
		III.a.	Pseudosageceras multilobatum subzone
II.	Genodiscus zone		
I.	Otoceras zone		

2. Schooler Creek Formation - Upper Triassic

Introduction

The Schooler Creek formation is restricted in its development as far as it concerns this thesis, to northern west-central Alberta and the Peace river block of British Columbia. This latter area is considered as the type section. The formation

is overlain by the Pine River shales of Jurassic age and, as yet, the lower contact has not been observed.

Previous Work

Sources of information regarding the stratigraphy of this area are limited. In 1875 Selwyn (141, p. 127) collected Monotis subcircularis Gabb, an Upper Triassic form, on Peace river in latitude 56°10' and longitude 122°10'. Two years later Hunter (141, p. 127) obtained the same species on Upper Pine river in latitude 55°30' and longitude 122°. In his report of 1889 on the fossils from the Triassic rocks of British Columbia, Whiteaves (171) made brief mention of these finds and described specimens including Spiriferina borealis, Terebratula liardensis, Monotis subcircularis, Popanoceras mcconnelli, and Trachyceras canadense, which he considered to be Upper Triassic in age.

Preliminary work on the Triassic of Peace river was carried out by McLearn (93) in 1917. Spieker (147) in 1922 carried on investigations in the British Columbia portion of the area, but his report mainly concerned the structure of the region. The first report on the lithology and faunal subdivisions of the formation is that of McLearn (97) in 1921. It was not until ten years later, however, that he described the fauna (107). A paper by Williams and Bocock (177) in 1932 and further important papers on the faunas of this formation by McLearn (113-117),

(186-189), followed in later years.

Lithology, Distribution, Thickness

It is considered that the Schooler Creek formation comprises all the known Triassic of the area. The main development of the formation is in the foothills of the Rocky mountains along the Peace river in eastern British Columbia. Beds of Upper Triassic age have not yet been found as far south as Jasper Park, although their occurrence there is quite probable as the Harvard geological field trip of 1929, under Professors Mather and Raymond claimed to have found Pseudomonotis subcircularis, an Upper Triassic form, at Jasper Park (120). At an early date Monotis circularis Gabb was reported farther south from a branch of the Brazeau river (84, p. 47).

In 1940 McLearn (117, p. 67) described the Schooler Creek formation as follows: "It is more than 2,500 feet thick and consists mostly of calcareous, very fine sandstone, ..., somewhat less of calcareous siltstone and less of shelly, crinoidal, partly oolitic, argillaceous and arenaceous limestone." Some of the shelly limestones are massive, while others, because of the presence of flat shells like Halobia and Monotis, have a fissile fracture on weathering. Thin beds of limestone consisting almost entirely of immature shells of Halobia, 2 to 3 mm. long, occur in the Halobia zone. A somewhat purplish color is exhibited by the formation. Williams and Bocock (177, p. 205)

gave a figure of 3,000 feet as a conservative estimate of the thickness of the formation.

Subdivision of the formation into definite, persistent, lithologic units is not readily accomplished. McLearn (117,p.67) has, however, designated the uppermost part of the formation consisting of dark, carbonaceous beds, including much calcareous siltstone, argillaceous limestone, and Halobia limestone, as the Pardonet member, and the lower part, which contains more light grey, less carbonaceous and more arenaceous beds, the lower or grey member.

Disconformably overlying the Schooler Creek formation are the Pine River shales, a probable northward extension of the Jurassic Fernie shale (117, p. 71). The basal contact with Pennsylvanian strata has not been seen in the foothills, but may be visible to the west in the mountains (107, p. 1).

Palaeontology of the Schooler Creek Formation

General Statement: The formation is very fossiliferous at some horizons and localities, all faunas being marine. McLearn (141, p. 67) has stated: "Ammonoids and pelecypods are common in number and diversified in species. Brachiopods are numerous at some horizons, but few in species. Gastropods are rare and Bryozoa very rare. Crinoid stems are common in some limestones. No corals have been collected. Some faunal facies consist mainly of ammonoids, others dominantly of pelecypods or

brachiopods. Some layers contain only Halobia or Monotis."

Faunal Zones: Faunal zoning of the Schooler Creek formation by both ammonites and pelecypods has been accomplished by McLearn (117, p. 68). While the pelecypods lend themselves very well to the zoning of the Triassic, they do not, however, permit as refined a zoning as do the ammonites. Brachiopods are insufficiently distributed throughout the formation to afford a basis for faunal zoning.

The following table by McLearn (117, p. 68) shows the ammonoid and pelecypod zoning of the Schooler Creek formation.

	Europe	Ammonoid faunas	Pelecypod faunas
	Rhaetian	Unknown	Unknown
Neo-Triassic	Norian	Diphyllites	
			M. subcircularis
		Distichites Drepanites	Halobia: M. alaskana var.
			Halobia: H. cordillerana, O. cf. mucronata, etc.
	Karnian	Stikinoceras	
			L ? poyana
Meso-Triassic?	Ladinian?		Mahaffy Cliffs Red Rock Spur
			M. montini
		Nathorstites	

Important species of the Schooler Creek formation with their zonal distribution include:

Nathorstites cf. mcconnelli Whiteaves - Nathorstites zone

Protrachyceras (Trachyceras) canadense (Whiteaves) -Nathorstites zone

Tropites sp. - Stikinoceras zone

Spiriferina borealis Whiteaves - Stikinoceras zone

Coenothyris (Terebratula) liardensis (Whiteaves) - Stikinoceras zone

Monotis subcircularis Gabb - Monotis subcircularis zone

3. Fernie Shale - Jurassic

Introduction

The Fernie shale of Jurassic age occurs in the foothills and mountains of western Alberta, extending from the vicinity of the 49th parallel northwestward to at least the northern boundary of British Columbia. In its northern development the formation bears the appellation Pine River shale. In the south in the Foothills, it lies unconformably on the Rundle limestone of Mississippian age, while in the Peace river area it rests on the Upper Triassic Schooler Creek formation. The change from the marine conditions of the Fernie to the freshwater environment of the overlying Kootenay is one of gradation.

Previous Work

The name "Fernie shale" has surreptitiously crept into

geological literature without the benefit of proper definition. To Leach (62) is attributed the first usage of this term in describing the rocks of the Blairmore-Frank coal fields. Dawson made the first section through the Crowsnest and erred in including in the Cretaceous the black shales at the base of the Kootenay. The early workers in the mountains and foothills followed this procedure. Mc Connell (87) and McEvoy (90) though they noted the black shales at the base of the coal-bearing beds, did not differentiate them as a distinct formation. Since its designation by Leach as the Fernie shales these beds have always been separated from the overlying Kootenay. It was not until after Dawson's death, however, that the name Fernie shale was admitted to geological literature.

Among the more recent workers who have contributed to our knowledge of the stratigraphy and palaeontology of the formation must be mentioned McLearn (92), (97), (98), (101), (103), (104), (106). It was his study of the ammonites which led to an appreciation of the faunal zones present in the formation. S. S. Buckman of England assisted him in this respect. C. H. Crickmay (19) contributed with his broad generalized studies, and Telfer (153) added much in his search for economically important phosphate deposits. The existing knowledge of the Fernie has been conveniently summarized by Warren (163).

Lithology, Distribution, Thickness

General Statement: The Fernie shale appears to vary lithologically from place to place. This apparent lithologic change may be largely stratigraphic as exposures are few, and thus the complete formation is rarely observed in any one section.

Of the general lithology of the Fernie, Warren (163,p.59) stated: "The formation is composed of a series of shales usually dark in colour, commonly sandy, in places calcareous and occasionally slightly bituminous. Clay-ironstone or calcareous nodules are common in many localities though entirely lacking in others. The sandy shales are generally platy whereas the more argillaceous types are more fissile and darker in colour. The calcareous shales weather to a light grey colour and assume a fine platy character especially when dry. Some sections show the three types of shale and this is especially true in the southern extension of the formation. Toward the north the formation becomes more sandy even to the inclusion of many thin sandstone beds and the calcareous type of shales disappear."

The base of the Fernie is generally marked by a phosphatic bed, which in some localities attains a thickness of 4 to 5 feet. In the south the persistence of the bed has been demonstrated by Telfer (153), but in some sections farther north it appears to be lacking as a definite unit, probably due to a change in character of the lower part of the Fernie through the

introduction of a bed of black chert with interbedded shaly layers at the base of the formation. The chert bed is especially well developed in the Cadomin area. At Clearwater it consists of chert and limestone*. This basal member, of which the phosphatic and chert beds are a part, is up to 125 feet thick and is always phosphatic. It is slightly fossiliferous.

Telfer (153, p. 589) stated that in general the Jurassic phosphatic seam may be divided into:

(a) An upper yellow marker
(b) A nodular or oolitic calcareous phosphate bed
(c) A shale parting
(d) An oolitic phosphate bed
(e) A basal marker usually marcasite

Overlying the basal phosphatic member is a series of black shales from 50 to 150 feet thick which are but very poorly fossiliferous.

Warren (163, p. 59) in 1934 stated that an excellent horizon marker consisting of calcareous sandstone is generally present within the Fernie and occurs from 50 to 150 feet above the base of the formation. For this bed he proposed the name Rock Creek member of the Fernie, from Rock creek near Blairmore, where the bed is well exposed. This member is the "Belemnite bed" of Telfer. The top of the bed is, in some places, more calcareous than the base. A variation in thickness of the bed of from 5 to 30 feet exists, the thicker sections being more arenaceous.

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* Personal communication from Dr. Warren.

the thinner sections more calcareous. A thickening of the bed to the east and to the north appears to take place. While Belemnites at this horizon are plentiful in some localities, as at Cadomin, in most places they are lacking. The Rock Creek member forms an important fossil horizon.

Overlying the Rock Creek member is a series of grey-black shales grading into the sandy beds of the Kootenay above. These latter sandy beds are but poorly fossiliferous, a fact which has been responsible for the inability of assigning to them a definite stratigraphic age.

The Fernie varies considerably in thickness from place to place. While a thickness of at least 800 feet can be measured in most sections (163, p. 58), thicknesses of 2,800 feet and over (90), (65), (70), (72), have been reported. Because of the soft character of the formation, exposures are few, and this, in conjunction with imperceptible duplication and faulting through orogenic movements, is in large part held responsible for the discrepancy in thickness as reported for various sections. Some areal variation in thickness is, however, believed to exist.

Fernie and Crowsnest Districts - The Type Section: The Fernie shale has derived its name from the town of Fernie, British Columbia, and for this reason the type section may be considered to be in this locality. A thickness of 3,000 feet for the formation in this area was reported by McEvoy (90), but

Warren (163, p. 60) considered that, because of the disturbed attitude of the strata in this region, no reasonable section could be measured. The age of the formation was based on the determination of Cardioceras collected by McEvoy in this area, and described by Whiteaves (175).

Good sections of the formation are exposed about 15 miles to the east of Fernie in the mountains west of the Corbin coal mine. Telfer (163, p. 60) measured the following section on Leach creek in this area:

	Overlying beds, Kootenay Sandstone
132 feet	Black shale
510 "	Grey calcareous shale
60 "	Black shale with some calcareous shale with nodules at base
160 "	Black shale
7 "	Calcareous sandstone (Belemnite bed) (Rock Creek member)
50 "	Black shale
1.5"	Grey limestone (bituminous)
4 "	Phosphate bed
924.5 feet	
	Underlying beds, Spray River Formation

A few miles to the east of this locality Warren (163) assigned a thickness of 800 feet of beds to the formation, and pointed out that the difference in thickness between his and Telfer's sections could probably be accounted for by the repetition or omission of strata. At the phosphate mine about one mile west of Crowsnest the section is 808 feet thick and very similar lithologically to the above sections. The strata in these

three sections are tilted but otherwise not greatly disturbed by faulting and folding, and are considered as typical sections of the Fernie in the type locality. A section at Corbin intermediate in position between the first two and the last mentioned sections, was reported by MacKay (70) to have a thickness of 2,800 feet. The strata in this locality are, however, notably broken and disturbed.

McLearn (104) considered the Fernie in the section on the south slope of Grassy mountain near Blairmore, to be resting on a quartzite of Palaeozoic age belonging to the Turtle mountain group. MacKay (72) assigned a thickness of 900 feet of beds to this section which includes 50 feet of strata which are doubtfully Jurassic. Calcareous shale in this eastern section is less frequent than in the sections to the west.

Of the lithology of the Fernie in the Crowsnest pass area MacKay (73) in 1933 stated that it consists of thin-bedded, grey-black and black, fissile, marine shales with thin-bedded, brown sandstone, fossiliferous calcareous grits, and in places a phosphate bed at the base containing Gryphaea. Limestone beds or lenses occur sparingly throughout the shale (123).

Warren (163, p. 61) concluded that: "The typical sections in Crowsnest pass and vicinity, therefore, show the Fernie shale to be less than 1,000 feet thick with a considerable development of calcareous shale in the west which is absent for

the most part in the eastern sections."

It is not known to what extent the Fernie extends south of the Crowsnest pass. Daly (20) in his survey of the International boundary did not identify the formation there, but it is possible that it may be obscured completely by detritus and thus have been overlooked. It seems probable, however, that the Fernie extends into Montana for the Ellis formation of Montana is by palaeontological evidence of the same age as the upper part of the Fernie.

Turner Valley: Information regarding the Jurassic of the Turner Valley area has been obtained solely from well logs. Hume (54, p. 3) has described the Fernie here as a marine formation containing phosphatic material and consisting of brown, thin-bedded sandstones at the top and dark to black shales with thin, limy bands in the lower part. The Fernie here contains the so-called "Brown sand", a granular brown sandstone 60 to 80 feet thick - the top of which marks the Kootenay-Fernie contact (52). In the upper of the underlying shales glauconite with abundant pyrite is present, and belemnites and phosphatic nodules occur. A belemnite conglomerate in sandstone with black, phosphatic pellets, is present about 160 to 170 feet below the top of the Brown sand. Between this conglomerate and the underlying Palaeozoic limestone are 40 to 50 feet of beds designated as "poker chip" shales, from their habit of breaking into

rounded chips. Hume gave the thickness of the Fernie in this area as 200 feet. Here, as at Moose Mountain, the Fernie shale lies disconformably on the Rundle limestone of Mississippian age.

Moose Mountain: Cairnes (15), (16), who carried out the early work in this area, assigned a thickness of 100 to 250 feet of beds to the formation. Hume (72) gave the thickness of the Fernie shale exposed in Canyon creek at Moose mountain as 205 to 220 feet. It is composed of dark brown to black shales with a highly bituminous appearance with intercalated calcareous shales, and a development of an arenaceous phase in the upper part. In this area the Fernie lies disconformably on the Mississippian Rundle limestone and is overlain unconformably by the Kootenay.

West-Central Alberta: In the following discussion west-central Alberta is considered as that area which extends from the Fallentimber area northwestwards to the vicinity of Jasper Park.

The thickness of the Fernie shale in the Fallentimber area was estimated by MacKay (76) to be 150 feet. The formation was recognized as being present on the Red Deer river, for Whiteaves (176) described a species of Peltoceras collected by Dowling from this area. From the Bighorn basin a thickness of 722.5 feet of predominantly dark grey or black calcareous

shales was reported by Malloch (84). He mentioned, however, a section between the Red Deer and Clearwater rivers attaining a thickness of 2,900 feet, but experienced difficulty in separating the Fernie from the overlying Kootenay. A complete section of the Fernie was measured by Allan (178, p. 35) in the head of the small valley entering Blackstone river from the north and directly opposite the valley of George creek. The Rock Creek member is developed to a thickness of 8 feet in this section of 685 feet of Fernie beds. The formation is underlain by the Spray River and overlain by the Kootenay.

To the east of this area in the Saunders Creek and Nordegg coal basins, Allan and Rutherford (3) assigned a thickness of 250 to 300 feet to the Fernie, the upper part of which is predominantly sandstone. The basal bed is black chert intermixed with shale. In this section no Kootenay was found, the Fernie being considered to carry up to the Blairmore conglomerate. Sanderson (139) described the Fernie in this area as composed of dark shales, brown, fine-grained sandstones, and ferruginous sandy beds. The presence of a Belemnite horizon was noted. Sanderson reported a thickness of 400 to 450 feet for the Fernie but said there is doubt as to the Triassic or Jurassic age of the basal 100-foot limy series.

Of the occurrence of the Fernie shale in the Mountain Park area northwest of Nordegg, Warren (163) remarked that the

formation is well exposed through intermittent exposures. The black chert member, containing poorly preserved pelecypods and belemnites, is well developed at the base of the formation to a thickness of over 20 feet. About 150 feet above the base the Rock Creek member is developed to a thickness of at least 30 feet. Overlying this member the shales are dark grey to black, arenaceous in character, and grade upwards into the Kootenay formation. The Fernie here is underlain by the Spray River formation, the upper beds of which are white limestones. Because of faulting and folding the true thickness of the Fernie has not been accurately obtained. MacKay (71) reported a thickness of 1,300 feet for the Fernie in the coal areas in the vicinity of Jasper Park. The Fernie has been recognized in the Smoky, Hay and Berland river areas by J. MacVicar (83).

Peace River Area: Overlying the Upper Triassic Schooler Creek formation and underlying the continental Lower Cretaceous beds on Peace river, is a shale of lithologic character similar to the Fernie, and occupying the same stratigraphic position. The name Pine River formation was given to these strata by Spieker (147, p. 118) who assigned them to the Jurassic (?). He described them as blue-black marine shale with intercalated limestone and some sandstone. He ascribed to them a thickness of 300+ feet but the base is not exposed. Williams and Bocock (177)

credit to the formation a thickness of 600 feet. This shale is also found north of the Peace about half way between Schooler creek and Ottertail river, and was correlated with the Pine River shales by McLearn (177, p. 207). There seems little doubt, that, lithologically and stratigraphically, the Pine River formation is the northern extension of the Fernie shale (163, p. 63).

Character of the Boundaries

In any section thus far studied the lower boundary of the Fernie is disconformable. Where the Fernie shale overlies the Lower Triassic Spray River formation the contact is gradational, the phosphatic bed at the base of the Fernie being very similar to some of the beds of the Spray River. However, where the Fernie overlies the Rundle limestone of Mississippian age, as it does in the foothills, the lithologic change is remarkably abrupt.

In most places the shale of the Fernie grades upwards, by the intercalation of sandstone beds, into the overlying Kootenay. In only one locality, the Moose Mountain and Turner Valley sections, is the contact unconformable. In areas where the Fernie is represented by its normal thickness the highest fauna thus far found, in the formation is Argovian (cf. p. 39) in age. The oldest flora of the Kootenay is said to be Barremian (cf. p. 59) of the Lower Cretaceous in age. It is thus evident that some

error exists in the section, but a consideration of it lies outside the scope of this thesis.

Faunal Horizons

To show the relationships of the fauna of the Fernie to the European, the following table of the standard European nomenclature of the Jurassic is given.

UPPER JURASSIC		Tithonian
		Portlandian
		Kimmeridgian
		Argovian
		Divesian
		Callovian
		Bathonian
		Bajocian
LOWER JURASSIC (LIAS)	Upper	Aalenian
		Toarcian
		Domerian
	Middle	Pliensbackian
		Lotharingian
	Lower	Sinemurian
		Hettangian

The earliest knowledge we have of the age of the Fernie shale was the identification by Whiteaves (172) of a Sonninian fauna, collected by McConnell (87) in an early reconnaissance in the vicinity of Devil's lake (Lake Minnewanka), near Banff. Whiteaves unfortunately placed this fauna in the Lower Cretaceous, and it was not until later years that the age of this fauna was correctly determined to be Jurassic (101).

It was the identification and description by Whiteaves (175) of a species of Cardioceras, which had been collected by McEvoy about two and a quarter miles northeast of Fernie, B. C., that gave us the first evidence as to the Jurassic age of the Fernie shale. This datum was further augmented by the discovery on Red Deer river of an ammonite described by Whiteaves (176) as Peltoceras. It was on the basis of these two finds that Whiteaves correlated the Fernie shale with the Ellis and Sundance formations of the western United States. Both genera apparently represent a closely related horizon in the Upper Jurassic and correspond to the fauna of the deposits of the Logan sea - the Upper Jurassic seaway which probably extended eastwards across the western United States. An arm of this sea extended northwestwards from Montana into Alberta. It was thus generally considered that the Fernie shale represented a deposit of a northern extension of the Logan sea. More recent work proved this assumption to be incorrect. While the Ellis-Sundance horizon has been shown to be present in the Fernie shale at certain localities, most of the formation is older than any horizon so far discovered in the deposits of Logan's sea.

The lowest fauna so far discovered in the Fernie shale is the Sinemurian (Lower Jurassic) fauna from the Fernie area, B.C. (160). Telfer obtained this fauna from several localities at

the very base of the formation. Poorly preserved pelecypods and ammonites were ascribed to the genus Arniotites by Warren (160), who stated that better preserved material shows that the genus is probably Eparnioceras. Warren (163) reported that this same genus has since been obtained from the base of the Fernie near Banff, and a fauna of probably similar age, as yet undescribed, occurs in one locality in the Jasper area. As these faunas have all been obtained from the very base of the formation, it has reasonably been assumed that no faunas earlier than the Sinemurian occur in the Fernie shale.

From some localities poorly preserved specimens with Liassic affinities have been collected. Distinct affiliations with "Grammoceras" were shown by ammonites collected from the Fernie district by Telfer from above the Eparnioceras zone. Allan and Rutherford (163, p. 66) in the Jasper area collected an ammonite which is undoubtedly a Dactylioceratid. A Dactylioceratid-like ammonite was also reported from near the base of the formation at Moose mountain by Hume (45). Both these are Upper Lias types. L. W. Collet (18) also obtained Upper Lias ammonites in the Jasper area. He identified these as Hammatoceras insigne Schubler and Dumortieria or Catulloceras sp. ind., and regarded them as Upper Toarcian in age. The significance of these finds rests in their demonstrating the presence of several definite

Liassic horizons in the Fernie shale, and in the probability that most of Lower Jurassic time is represented in the lower part of the formation.

Probably the best known faunas in the Fernie are those of Bajocian (lowermost Upper Jurassic) age. The first one is that found by McConnell (87) near the north end of Lake Minnewanka. Here ammonites representing the genus Sonninia (lower Bajocian in age) are present together with brachiopods and pelecypods. This fauna was originally ascribed to the Cretaceous by Whiteaves (172) but was properly placed at a later date by McLearn (101). As yet the ammonites have not received full study, but the molluscs represent a very definite group including Ostrea, Plagiostoma, Oxytoma, Trigonia, Astarte, Protocardia and Pleuromya. As yet this fauna has not been found elsewhere.

Warren (163) has stated that at a slightly higher horizon and in the Rock Creek member of the formation a more widespread and very prolific fauna occurs. Included are such ammonites as Teloceras, Stemmatoceras, Defonticeras, Saxitoniceras, and Zemistephanus together with a variety of other forms including Belemnites, Rhynchonella, Cucullaea, Inoceramus, Oxytoma, Cardinia, Trigonia, Camptonectes, Entolium, Plagiostoma, Pleuromya, Thracia, Arctica, Protocardia and Pleurotomaria. "This fauna has now been obtained in practically every locality examined from Crowsnest pass to Jasper Park." (163, p. 66). Crickmay (19) reported it

in close association with the Sonninian fauna near Lake Minnewanka. Allan (178,p. 35) reported this same fauna from Blackstone gap. Belemnites cf. densus M. & H., Trigonia sp. nov., Inoceramus sp. nov., Plagiostoma sp. nov., Cyprina sp. nov. and Pleuromya sp. undet. are represented at this locality. Close relationship appears to exist between the pelecypods of the three faunas. On account of the abundance of specimens which may usually be obtained when the horizon is found, this Teloceras fauna will probably prove the best horizon marker in the Fernie shale. Most of the other faunas, especially those of the Lower Jurassic, are known from a very few specimens.

McLearn (99), (101), (104), reported a fauna of somewhat similar age from calcareous sandstones (Lille member) at the top of the Rock Creek member on the south slope of Grassy mountain near Blairmore. This is the Chlamys mcconnelli fauna of McLearn and consists of pelecypods including Chlamys mcconnelli, Lima stantoni, Lima whiteavesi, Plagiostoma blairmorensis, Gryphaea, Alectryonia and Camptonectes. No ammonites are present but the position of the fauna in the Rock Creek member shows its close association with the Teloceras fauna even though the pelecypods are quite distinct from those of other faunas found at this horizon.

Another assemblage of pelecypods together with some ammonites appear approximately 450 to 595 feet above the Rock Creek member. This is McLearn's (104) Corbula munda fauna.

Pelecypods are very abundant and include such forms as Cucullaea, Gervillia, Inoceramus, Oxytoma, Pseudomonotis, Ostrea, Gryphaea, Trigonia, Camptonectes, Entolium, Lima, Anomia, Modiolus, Pleuromya, Protocardia and Corbula. With these occur the ammonite species Miccocephalites miccus Buckman, Metacephalites metastatus Buckman, and Paracephalites jucundas Buckman. In describing the ammonites Buckman (182) assigned to them an early Upper Jurassic Proplanulitan (middle Callovian) age. This fauna is abundant in the Blairmore region and Warren (163) has found some elements of it in a section farther to the west. The presence of the horizon in localities farther north is shown by the discovery by McLearn (103) on Kananaskis river of the specimen Seymourites mcevoyi, an ammonite of Callovian age. The ammonites and pelecypods of the Blairmore region, however, are apparently absent. This fauna may prove to be a good horizon marker in the formation.

Two faunal horizons, as yet unfortunately both identified by but a single species and specimen of ammonite, are known above the Corbula munda or Miccocephalites horizon (163). The first is that from which Dowling obtained his Peltoceras occidentale Whiteaves (176) on Red Deer river in Rocky Mountain park. This fauna is undoubtedly younger than the Corbula munda fauna and as yet this horizon has not been recognized elsewhere in North America. The second horizon, Argovian in age, is marked by Cardioceras canadense Whiteaves (175). Cardioceras has a widespread

distribution in North America, being one of the characteristic elements of the fauna of Logan's sea. It has not, however, been found elsewhere in the Fernie shale and its exact position in the formation is not known (163).

At present, the Cardioceras fauna is the youngest fauna obtained from the Fernie shale. It was presumably found in the sandy beds transitional between the Fernie and the overlying Kootenay and thus near the top of the formation. In the Jurassic as now defined, it would thus appear that faunas of an age younger than the Argovian are hardly to be expected. Careful search for specimens in the beds transitional between the Fernie and the overlying Kootenay avails little, for these beds are remarkably barren of fossils, although the strata appears to have been deposited under marine conditions.

4. Kootenay Formation - Lower Cretaceous

Introduction

In this thesis the term Kootenay is restricted to the Cretaceous beds below the conglomerate in all areas. The conglomerate is defined as the Blairmore conglomerate or the Cadomin conglomerate, depending upon the area. In its northern development in the Mountain Park area the Kootenay is locally referred to as the Nikanassin formation, while in the Peace river

canyon it forms the Lower member of the Bullhead Mountain sandstone. The importance of the Kootenay lies in the exploitation of coal seams which are associated with this formation in the southern areas. Reference should be made to the correlation table p. 11 of this thesis.

Previous Work

In 1886 G. M. Dawson (24) proposed the term Kootanie for a succession of sandstones, interbedded with shales and shaly sandstones, including occasional beds of conglomerate and a zone containing coal seams. In his Kootenay he included the Jurassic Fernie shale, the Kootenay, and most of the overlying Blairmore formation.

It was on the basis of fossil plant determinations alone that a Cretaceous age was assigned to the formation. Sir J.W. Dawson (26), (27), determined as Lower Cretaceous some fossil plants from the coal-bearing beds in the Kootenay, whereas specimens obtained from the top of the section were believed to represent a Dakota flora and were, therefore, Upper Cretaceous in age. It was on this basis that the uppermost beds of our present Blairmore were excluded from the Kootenay, which term was reserved for the Lower Cretaceous. Dawson was cognizant of the presence of the conglomerate beds associated with the Kootenay series. He postulated a source from the underlying Palaeozoic limestones for the chert pebbles in the conglomerate. His section was

measured in the vicinity of the present town of Coleman.

Leach (62) in his study of the Blairmore-Frank coal fields in 1902 delimited the different formations as we now know them, but did not name them. He recognized our present Fernie shale (700 feet) at the base of the section, then the coal-bearing beds (Kootenay - 740 feet), followed by a conglomerate bed (Blairmore conglomerate - 30 feet) in turn overlain by his fourth series, our present Blairmore formation (1,850 feet). The conglomerate was always included with the Kootenay by Leach.

On his return to the Crowsnest pass area in 1911 Leach (63) named the formations he had previously delimited. For the coal-bearing beds above the Fernie he used Dawson's term Kootenay in a limited sense, including with it the conglomerate at the top which he designated the Kootenay conglomerate. For the beds above the conglomerate he applied the term Dakota? considering that there was no evidence of an unconformity here "unless the conglomerate at the top of the Kootenay should mark a short cessation of deposition at that period." (63, p. 195)

The Blairmore section was studied by Rose (123) in 1915 and 1916. He used the term Blairmore formation for the beds above the conglomerate and included the conglomerate in this formation rather than in the Kootenay. He had perceived that some of the coal seams of the Kootenay had been eroded off in

places, indicating an unconformity at the base of the conglomerate. In a study of the fossil plants of the Crowsnest section Berry (12) in 1929 suggested a Barremian age for the Kootenay flora. MacKay in 1931 (72), 1932 (73), and 1933 (74), restudied the stratigraphy and structure of the Crowsnest pass area. In all of his reports he placed the Blairmore conglomerate in the Blairmore at its base, and stressed the unconformity which exists between this bed and the underlying Kootenay (72, pp. 24-25), (73, p. 30), (74, p. 23).

The west-central and northwestern Alberta equivalents of the Kootenay formation are discussed in papers by Malloch (84), MacKay (68), (71), McLearn (93), (97), (98), (110), (117), MacVicar (81), (82), (83), Williams and Bocock (177), Spieker (147), Allan and Stelck (9), and Warren and Stelck (168). Warren (165) in 1938 reviewed the general relationships of the Kootenay from the vicinity of the International Boundary to the Peace River area.

Lithology, Distribution, Thickness

General Statement: In general the lithology of the Kootenay formation remains remarkably constant throughout the length of its areal distribution. The formation consists of alternate dirty dark grey-colored shales and drab buff-colored sandstone, with coal seams, and represents freshwater lake or subaerial deposition. The formation, or its equivalents, are known to extend almost continuously from the region just north of the

49th parallel northwestward to the Peace River country. The thickest sections are in the western part of the area, a remarkable thinning being experienced as the beds are traced eastwards. In most areas it overlies the Fernie shale of the Jurassic, the Fernie having passed upwards through a gradational zone into the Kootenay. Overlying the Kootenay, and separated from it by an unconformity in the Crowsnest pass area, is the Blairmore conglomerate.

Crowsnest Pass and Vicinity - The Type Locality:

Rose described the Kootenay formation in the Crowsnest pass area as consisting of alternating sandstones and shales and coal seams, with considerable conglomerate towards the top of the section. Massive, coarse-grained, cross-bedded, grey sandstones stand out prominently. Between these are black shales, sandy shales, and the coal seams which, on account of their softer character, have weathered more than the sandstones and are usually covered with detritus. The character of the sediments - coarse sandstones showing cross-bedding, ripple-marks, fossil land plants, and shales associated with coal seams - bespeaks of the sub-aerial origin of the formation. All the workable coal of the area is found in this formation. A prominent conglomerate marks the upper limit of the formation on the Alberta side in Crowsnest pass and in the Flathead valley, but in Crowsnest area in British Columbia a number of small coal seams occur above the first conglomerate.

One of the best sections of the district is that measured by Rose (123, p. 110) in 1916, which outcrops south of Crowsnest river at Blairmore. It serves to illustrate the nature and succession of the Kootenay sediments in this area and is as follows:

Section of Kootenay Formation at Blairmore

	Feet
Conglomerate at the base of the Blairmore formation	
No. 1 coal seam missing but present under the conglomerate $1\frac{1}{2}$ miles to the north where it has a thickness of 10 to 18 feet.	
Massive, coarse-grained, and cross-bedded, grey sandstone with prostrate fossil stems and bits of coal	39
Coal, No. 2 seam	15
Dark shale	55
Sandstone, dark grey, cross-bedded	14
Shale, black, fissile with a few sandy layers	25
Coal, No. 3 seam	2
Shale, black, sandy and carbonaceous layers with little layers of coal	81
Coal, No. 4 seam	4
Black shale	3
Coal	2
Black shale	3
Sandstone, coarse and cross-bedded	37
Shale and small coal seams	70
Massive, grey sandstone, approximately	100
Below is thin-bedded sandstone and shale assigned to the Fernie formation	
	450

For the Kootenay at Burmis at the east end of Crowsnest pass, MacKay gave a thickness of 400 feet, while farther west at Coleman the formation has thickened to 800 feet. (73, p. 36B). Across the divide in British Columbia in the Crowsnest field,

MacKay (74) ascribed a thickness of 3,610 feet of beds to the formation. The thickness of the Kootenay is thus seen to increase greatly from east to west. Part of the variation in thickness is attributable to erosion of the Kootenay sediments before the Blairmore formation was deposited, but most of it is imputed to variations in depositions.

Southern Distribution: The Kootenay formation has never been reported as far south as the International Boundary. Daly (20) in his survey of the 49th parallel reported no rocks of Kootenay age. In the southern area east of the Clarke range Stewart (151) found no rocks referrable to the Kootenay-Blairmore group, although he mentioned that they might exist in an unmapped area immediately east of the front ranges. The farthest south that the Kootenay formation is known to outcrop in Canada is in the Flathead valley in the mountains just north of the International Boundary (79). The formation is exposed in this basin for about six miles but does not extend as far south as the 49th parallel.

On the South Fork of Oldman river (Castle river), MacKenzie (77) gave a thickness of 1,285 feet for the Fernie (base not exposed) and Kootenay combined. He included the conglomerate, of thickness up to 25 feet, in the Kootenay. Stewart (151) stated that the total thickness of the Kootenay in the foothills in the disturbed belt of southwestern Alberta is 600 to 750

feet, with the coal seams confined to the upper 300 feet.

Turner Valley: Slipper (146) provisionally referred 400 feet of beds to the Kootenay formation in the Sheep river area in 1921. In Turner Valley Hume (52) in 1939 reported an average thickness of 20 to 100 feet for the Kootenay, but said that some sections may be slightly thicker. He described the Kootenay as consisting of brown, hard sandstones alternating with dark shales and containing coal in the upper part. (54). The Kootenay formation was recognized by Rose (126) in the Highwood coal area where it is typically developed.

Moose Mountain and Vicinity: In the Moose Mountain area Cairnes (16) reported an average thickness for the Kootenay of 340 feet. He suggested that the fossil plants might belong to the Jurassic rather than to the Cretaceous. An increased thickness is reported for these same beds where they outcrop farther west behind the front range at the head of the south branch of Sheep creek at the Burns mine (165, p. 12).

Southern West-Central Alberta: In the present discussion, southern west-central Alberta is considered to include that portion of Alberta from the Bow river north to Ram river.

Between the Bow and Kananaskis rivers Malloch (84, p.34) in 1911 reported a probable thickness for the Kootenay of 2,800 feet, and stated that the uppermost beds have been removed by erosion. Information obtained from core samples of Wabash oil well

No. 1, Stoney Indian Reserve, near Kananaskis, shows a thickness of 599 feet of Kootenay strata (38). Rutherford* reported the Kootenay as also exposed at the Roxana well. MacKay (76) estimated the thickness of the formation in the Fallentimber area as 500 feet. In the first longitudinal valley south of the Red Deer Dowling (184, p. 8) gave the thickness of the formation as about 1,700.

Hume (165, p. 13) stated that 150 feet of Kootenay beds with coal are exposed on Red Deer river east of Hunter valley well. The conglomerate overlies the Kootenay while the base of the formation is faulted. At Marble mountain, on Tepee Pole creek, a tributary of the James river on the north side, the Kootenay is practically gone, the conglomerate resting on the Fernie shale which becomes sandy in the upper beds (165, p. 13). No coal is present at this locality. A section measured on Ram river by Evans (38) shows 207 feet of Kootenay with the base covered. Malloch (84, p. 34) stated that in the third longitudinal valley between Red Deer and the Clearwater, at least 2,300 feet of Kootenay strata remain, the uppermost strata having been eroded off.

West-Central Alberta: West-central Alberta is in the present discussion considered to extend from the vicinity

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* Personal communication.

of Nordegg north to the Athabaska river.

* In the area around Nordegg Allan and Rutherford (3) have shown that the conglomerate at the base of the Blairmore lies directly on the Fernie, the upper beds of which are sandy and probably marine. They have followed the procedure adopted in this area of applying the term Kootenay to the coal measures above the conglomerate, whereas in other areas to the south, beds above what is considered to be the same conglomerate, are called Blairmore. Stewart (150) in 1917 in this same area also referred the coal-bearing strata to the Kootenay. Sanderson (139) in 1939 reported that no Kootenay was present in the area, the Blairmore conglomerate resting directly on the Fernie.

In the Bighorn coal basin west of Nordegg, Malloch (84) reported a thickness of 5,459 feet for the beds which we now term Kootenay and Blairmore, consisting of 3,659 feet of Kootenay beds and 1,799 feet of Blairmore beds. His subdivision of the succession, however, was not made at the conglomerate. Were such a division made, the thickness of the Kootenay would then become 1,467 feet and that of the Blairmore 3,991 feet. The lithology of the formation here is typical of the Kootenay, and the strata show an entire want of regularity, the beds differing in thickness and character in localities situated at short distances from one another.

* (cf. p. 45).

North of the Nordegg area along the Blackstone, Brazeau and Pembina rivers, Allan and Rutherford (4) employed the term Kootenay for the entire Kootenay-Blairmore succession. They subdivided their Kootenay, on the basis of difference in lithologic appearance alone, into two members, - the upper, the McLeod member, which corresponds to the upper part of the Blairmore, and the lower, the Coal-bearing member which includes the lower Blairmore, the conglomerate, and the underlying sandy beds. The lithology of the Kootenay here is similar to that of the formation in the Bighorn basin. Allan and Rutherford (4, p. 24) have described their Kootenay in the area as consisting of alternating beds of conglomerate, sandstones, clay shales, carbonaceous shales and coal seams. Most of the coal, however, is above the conglomerate. No good measurements of the thickness of the formation were made in this area.

In continuing this work to the north to Athabaska river, Rutherford (132) employed the same nomenclature. In most of the area the beds are too badly deformed for a reasonable estimate of the thickness to be made, but on Folding mountain he reported a thickness of 900 feet for the beds below the conglomerate. McEvoy (89) in 1899 issued an earlier report on this area.

Reports on the geology of the area along McLeod and Athabaska rivers are also given by MacKay (68), (71). He introduced

a new set of formational names to facilitate the mapping of geological units in this area. Because the term Kootenay, as employed by earlier workers in this area, did not correspond to its usage in southern Alberta where it had a definite age significance, its use was discontinued by MacKay. He introduced the term Cadomin conglomerate for the conglomerate bed of the area, while for the formation below the conglomerate he employed the term Nikanassin (68, p. 7). This lower member is barren of noteworthy coal seams in this area, the coal horizons being present in the formation above the conglomerate. In the Brule area MacKay (68) gave a thickness of 1,046 feet for the Nikanassin, while in the vicinity of Jasper Park (71) he ascribed a thickness of 1,900 feet of beds to the formation. Lithologically, the Nikanassin consists of dark grey shales, and brown-weathering grey sandstones with thin impure coal seams.

Our knowledge of the Kootenay north of the Athabaska is largely confined to three reports by Mac Vicar (81), (82), (83), His term Kootenay includes all the coal-bearing beds and extends down to the top of the Fernie. For the thickness of his Kootenay he gives 3,600 feet in the southern division of the map-area, and 2,500 feet in the northern division. Two conglomerate beds each approximately 45 feet in thickness enter the section, thus making correlation with the Athabaska river section difficult.

Peace River Canyon: The most promising key section to the problems of the Lower Cretaceous in the foothills is this northwestern area (110, p. 165). Early work in this region was carried on by Selwyn (141), G. M. Dawson (21), McLearn (93), (97), (98), and Stewart (150). Later investigators included Rutherford (136), Spieker (147), Williams and Bocock (177), McLearn (110), (117), and C. R. Stelck (9), (168).

The Lower Cretaceous of this area was subdivided by McLearn (93) in 1918 into two formations, the lower, the Bullhead Mountain sandstone and an upper, the St. John formation. Subsequently (98) McLearn has further subdivided the Bullhead Mountain sandstone into a Lower member, and an upper member, the Gething member.

In his latest report McLearn (117, p. 72) suggested that a conglomerate bed comparable to the Blairmore and Cadomin conglomerates, may exist between the Lower and Gething members of the Bullhead Mountain sandstone. It is the Lower member which alone concerns the present discussion.

McLearn (98) in 1923 described the Lower member as consisting of conglomerates, grits, and coarse sandstones with minor amounts of medium to fine sandstones and shale. Some of the grits and sandstones show large-scale cross-bedding and some layers are ripple-marked. Shale, sandstone, and occasional, fine

conglomerate comprise the basal beds (117, p. 71). The lower part of the formation generally consists of thin and thick bedded, grey sandstone of about medium sand grade, and contains a few poorly preserved marine pelecypods. Higher up, the formation consists of fine conglomerate, sandstone, some dark carbonaceous shale, and occasionally very thin coal seams. Impressions of large tree trunks and woody debris are present in some of these beds. This zone passes gradually into the Upper or Gething member. The contact between this Lower member and the overlying Gething member is arbitrarily drawn by McLearn where conglomerates and grits disappear, coarse sandstone becomes rare, and medium to fine sandstone, shale, clay ironstone, and coal beds become common. The thickness of the formation in the vicinity of the Peace River canyon is known to be over 3,000 feet, with a thickness of 1,400+ feet for the Gething member (98). On Pine river Williams and Bocock (177) did not subdivide the Bullhead Mountain formation and assigned to it a total thickness of 3,500 feet. In this latter section two beds of conglomerate enter. The lower is about 30 feet thick while the upper one is some 20 feet in thickness.

The upper part of this member is probably of non-marine origin although as yet no fossils have been found in it. The lower part of this member is to some extent at least marine and

contains some marine invertebrate fossils.

In the Wapiti river basin Evans and Caley (39) reported the probable presence of the Bullhead Mountain sandstone overlain by the St. John shale. At the Guardian No. 1. well in Tp. 80, R. 12, W6th, two miles east of Pouce Coupe creek, Allan and Stelck (9) reported the absence of the Kootenay formation.

Fossils of the Kootenay Formation

As a discussion of the Cretaceous formations in the area under review has necessitated the usage of European time equivalents, the following table of standard European nomenclature for the Cretaceous is given.

UPPER CRETACEOUS	Danian	
	Senonian	Maestrictian
		Campanian
		Santonian
	Emscherian	(Coniacian)
	Turonian	
	Cenomanian	
LOWER CRETACEOUS	Albian	
	Aptian	
	Barremian	
	Neocomian	Hauterivian
		Valanginian

The life of the Kootenay time was almost entirely floral and included ferns, cycads and conifers. In 1885 Sir J. W. Dawson (26) described specimens collected by G. M. Dawson in the Rocky Mountain region in Alberta in 1884, as bearing affinities to the Cretaceous. Further contributions to our knowledge of the Kootenay

flora have been made by Berry (10), (11), (12), by Warren (155), and by Bell (70, pp. 160-161A), (74, p. 63). The type locality may be considered to be in the vicinity of Kootenay pass, but perhaps most of the collections have been made from the Crowsnest area.

The most characteristic and abundant species as given by Berry (11, p. 29) from the Crowsnest region are Onychiopsis psilotoides, Oleandra graminaefolia, Cladophlebis montanensis, Cladophlebis heterophylla, Pterophyllum acutipennis, Podozamites lanceolatus, and Ginkgo arctica. Of these Berry said that the Podozamites is not of especially good botanical standing, and all the others but Oleandra and Cladophlebis heterophylla occur also in the Lower Blairmore. However, the presence of these two forms and the absence of dicotolydonous leaves are the best field guides for recognizing the Kootenay.

Other less common forms which differentiate the Kootenay from the Lower Blairmore are Cladophlebis virginiensis, Acrostichopteris fimbriata, (no member of the genus Acrostichopteris being known from the Blairmore, although it continues to the close of the Lower Cretaceous in Wyoming and the east), Cycadolepis sp., Nilsonia schaumburgensis, Czekanowskia sp., Baiera sp., Nageiopsis zamioides, and Nageiopsis (?) montanensis.

W. A. Bell examined specimens obtained by MacKay (70, pp. 160-161A) from the Corbin area to the west of the Crowsnest pass. Of the species in this area Cladophlebis virginiensis Fontaine and Ptilophyllum arcticum Heer were most abundantly represented. In addition to these two species, which were also found in the Michel coal area, MacKay (74, p. 6B) reported that Nilsonia schaumburgensis (Dunker) and Pityophyllum graminaefolium (Knowlton), as identified by W. A. Bell from the Michel area, are common components of the Kootenay flora. A Coniopteris sp. was also found but it is represented but sparingly in the floral assemblage of the Kootenay, occurring more commonly in the Lower Blairmore.

Only a relatively few well preserved plant species were obtained from the Nikanassin formation and the majority of these were similar to those found in the Kootenay strata of the Blairmore area (71).

A study of the table of distribution of forms identified by Berry (12) in the Crowsnest region, shows that of the forms identified, "eleven of them are common to the Kootenay of other areas and six occur in the Bullhead Mountain sandstone; six in the Lower Blairmore ..... The only species common to the Jurassic or Upper Cretaceous is the composite species Podozamites lanceolatus, which lacks both botanical and chronological significance." (12,p.30).

In the lower part of the Bullhead Mountain sandstone some marine invertebrate fossils were found. These include Aucella, good specimens of which were collected by J. B. Bocock on Falls mountain, Pine river. McLearn considered that the presence of the Aucella fauna shows that the lower part of the Lower member of the Bullhead Mountain formation is of Neocomian and early Lower Cretaceous age. The Lower member of the Bullhead Mountain formation may thus possibly be correlated with the Nikanassin formation of the Mountain Park area and the Kootenay formation of the southern foothills area. Berry (12) however, considered the Kootenay in the main to be correlative with the Barremian stage of the European time scale.

5. Blairmore Formation - Lower and Upper Cretaceous

Introduction

The Blairmore formation, in the main of Lower Cretaceous age, extends the length of the thesis area, that is, a distance of approximately 500 miles from the International Boundary northwestward to the Peace River canyon. Only in its southern development does the formation bear the appellation Blairmore, for in its development in west-central and northern west-central Alberta it has been subdivided and has been given various names. While in the southern foothills the Blairmore is barren of coal, in its more

northerly development the formation contains numerous coal seams. In the north, marine conditions of deposition largely superseded the continental deposits of the south.

Previous Work

Most of the strata now grouped in the Blairmore formation were first included in the Lower Cretaceous Kootenay series of G. M. Dawson (24). The upper part of the formation, however, contained fossils determined by J. W. Dawson (26) as bearing affinities to a Dakota flora and was therefore of Upper Cretaceous age.

The Blairmore formation as we now know it was delimited, but not named, by Leach (62) in 1902 during his work on the sections at Blairmore and Coleman. He placed about 1,850 feet of beds in this division. Our present Blairmore conglomerate was included by him in the top of the Kootenay. In 1912 (63) he named this group the Dakota and considered that it overlay the Kootenay without evident unconformity unless the conglomerate at the top of the Kootenay should mark a short erosion interval. In the following year Leach (64) introduced the term Blairmore (Dakota?) for the beds above the conglomerate.

In 1915 and 1916 the Blairmore section was studied by Rose (123). He used the term Blairmore formation for the beds above the conglomerate and placed the conglomerate in the Blairmore rather

than in the Kootenay as he noticed an unconformity at the base of the conglomerate.

On the basis of fossil plant evidence McLearn (92) in 1916 suggested a Dakota age for the upper 200 feet and an uppermost Comanchean age for the remainder of the section. Rose (126) in the Highwood coal area referred the Blairmore formation to the Upper Cretaceous. Stewart (151) in 1919 included the conglomerate in the Blairmore and placed the top of the formation at the base of the Crowsnest volcanics. In 1932 MacKay (72), (73), (74), placed the conglomerate at the base of the Blairmore and included the whole formation in the Lower Cretaceous.

Berry (12) in 1929 considered the flora of the Lower Blairmore to be of an Aptian-Albian age and that of the uppermost Blairmore to be Cenomanian in age. Warren (165) in 1938 reviewed the regional relationships of the Blairmore formation, special emphasis being given to the Blairmore conglomerate. In all cases the Blairmore formation includes all the strata in the Canadian Rockies described as Dakota.

Lithology, Distribution, Thickness

General Statement: On the whole, the Blairmore formation remains remarkably constant in lithologic character throughout its distribution. MacKay (72, p. 22) described it as consisting in general of massive, crumbly, sandy shales of various

colors, including green, grey, brown, red and black, interbedded with minor amounts of massive, soft, greenish-grey, coarse-grained and shaly sandstones. Occasional thin beds of ironstone and at least one rather persistent bed, 10 to 15 feet thick, of bluish grey, shaly limestone which in places is fossiliferous, are present.

At the base of the Blairmore formation is a persistent bed of conglomerate known in the south as the Blairmore conglomerate and in west-central Alberta as the Cadomin conglomerate. McLearn (117) in 1940 suggested the possibility of it being present between the Lower and Gething members of the Bullhead Mountain sandstone in the Peace River canyon area. This conglomerate has been correlated with the Cloverly conglomerate of the United States (59). This latter conglomerate, or its equivalents, have been traced from the Alberta-Montana border to southern Colorado.

Warren (165) stated that it varies little in lithologic character throughout the foothills and mountains, being composed of pebbles of chert and quartzite cemented in a matrix of usually calcareous sandstone. The quartzite pebbles vary in color from white to a buff or yellow, whereas the chert may be grey, blue or pink in color. The proportion of chert to quartzite varies from place to place, in some places chert predominating, while in others quartzite is more common. Generally, they are well mixed. Variation in proportion of matrix to cobble seems to bear a distinct relation-

ship to the position of the outcrop with reference to the old shoreline. As a rule, the cobbles, which usually make up over 50 per cent of the total volume of the bed, appear as the predominant part of the stratum.

The Blairmore is a well sorted conglomerate. Although a variation in size exists between the pebbles in one exposure from those in another, in any one exposure the size remains remarkably alike. While an inch in diameter is the average size for the cobble and pebbles in the foothills, it may vary from half an inch, (seldom smaller), up to three inches in diameter. In Crowsnest pass, in the Michel and Fernie fields, they may be found still larger and the amount of sandy matrix proportionately less, such changes being accounted for by the proximity of these areas to the old shorelines. Warren (165, p. 10) stated that "it seems to be a fact, nevertheless, that the conglomerate disappears towards the east not so much by the pebbles becoming finer and finer, but by the pebbles becoming fewer and fewer in the sandy matrix."

Variation exists too in the shape of the pebbles. They have all undergone water erosion for they are flattened to some degree and are roughly oval in outline, although seldom are they of the flatness of well-worn beach pebbles. The chert pebbles are usually more angular than those of the quartzite even though they may be far from their source of supply. Such angularity is probably the result of breakage in transit.

The writer has received the following personal communication from Dr. Rutherford:

"Conglomerates within the Blairmore formation have been reported from several localities in the foothills especially to the west of the outer structures (72), (73), (77), (123), (126). These differ from the basal conglomerate in that they frequently contain pebbles of igneous rocks mainly fine-grained porphyries. Such pebbles have never been observed in the basal Blairmore conglomerate. Hume records one of these higher conglomerates on Highwood river where it has only a local distribution. Here in section 34 - Tp.18 - R. 2 - W5th it has a thickness of 75 feet* and contains numerous pebbles of porphyry. Hume (52, p. 7) reports pebbles of similar rocks from the Blairmore in some of the well samples in Turner Valley.

"The conglomerate carrying porphyry pebbles is well developed to the north end of the Moose Mountain structure and is well exposed in Tp. 24 R. 7 and 8-W5th. Here it occurs about 1,000 feet above the basal conglomerate and consists of a coarse sandstone zone about 25 feet thick containing numerous lenses of conglomerate. It is not so well indurated as the basal conglomerate".

The Blairmore formation or its equivalents are believed to extend from just north of the 49th parallel to at least as far north as the Guardian No. 1 well east of Pouce Coupe river in the

* Dr. Rutherford.

Peace River area, a distance of some 500 miles. The formation thickens greatly to the west as it approaches the old shoreline. For the standard European nomenclature of the Cretaceous reference should be made to page 59 of this thesis.

Crowsnest Pass and Vicinity - The Type Locality: Rose (123) in 1917 described the Blairmore formation as consisting principally of red and green, sandy and crumbly shales with interbedded grey sandstones. The base of the formation is marked by a persistent and conspicuous conglomerate 15 to 20 feet thick made up of black, white and red quartzite pebbles $\frac{1}{2}$ inch to 2 inches in diameter and firmly cemented in a sandy matirx. Rose first placed the conglomerate in the Blairmore, for he noticed an erosional unconformity at its base where in places some of the coal seams of the Kootenay had been eroded off. He contended that the pebbles of the conglomerate were derived from Cambrian and Precambrian quartzites to the west.

Rose (123) noted the occurrence at irregular intervals throughout the formation of conglomerate as lenses in the sandstones. One such persistent conglomerate band which looks much like the basal conglomerate, but is distinuished by a large percentage of crystalline igneous pebbles, occurs about 1,000 feet above the base of the formation. It is well exposed on York creek one quarter of a mile west of the International Coal and

Coke Company's fan house and again on the hills between Frank and Bellevue just north of the Turtle Mountain rock slide. A 10- to 15-foot bed of bluish grey, shaly limestone associated with shale and limy sandstone was seen to occur at several points. The presence of this bed indicates at least temporary brackish water conditions. Rose stated that at Passburg this limestone band is not more than 50 feet from the basal conglomerate, at Frank 175 feet from the base, at Blairmore 500 feet, and north of Coleman 550 feet. In 1912 Leach (63) reported observing on the east flank of McGillivray ridge a thin bed of volcanic material consisting of ash rock and agglomerate about 12 feet thick and about 250 feet above the base of the limestone bed. At no other locality did he find a trace of this. Should Leach's determination of the position of this volcanic bed be correct, its occurrence within the Blairmore is most unusual.

MacKay (72, p. 22), (73, p. 30) described the Blairmore formation as consisting of non-marine, light-colored, shaly sandstones and sandy shales alternating with red and green shales and with massive, hard conglomerate or coarse sandstone at base and loose, cherty conglomerate at top. This basal conglomerate is a massive, 20-foot bed of coarse, white cherty sandstone in the eastern part of the Blairmore district, whereas, in the vicinity of Hillcrest and Bellevue, small lenses of chert pebbles appear.

At least one bed, 10 to 15 feet thick, of bluish-grey, shaly limestone which in places is fossiliferous, and possibly several beds, of shaly, freshwater limestone, are present in the lower part of the formation. MacKay gave the thickness of the Blairmore formation as ranging from 2,100 feet at Blairmore to 3,000 feet west of Coleman.

The following is MacKay's (72, pp. 22-3) composite section of the Blairmore formation at Hillcrest.

BYRON CREEK SECTION

	Thickness Feet
Overlying formation - Crowsnest volcanics	
Coarse, grey-green, massive sandstone becoming shaly towards base	180
Green sandstone, interbedded with buff-weathering, green shale	215
Green, sandy shale, massive bedded in places; in part concealed	211
Green, shaly sandstone and shale, in part concealed	130
Light brown, buff-weathering, sandy shale	43
Interbedded green shale and sandstone, iron stained in places	135
Coarse, grey sandstone with bands of ironstone 18 feet from top	100
Green shale	15
Crumbly, green shale with a few bands of ironstone and green-grey sandstone	43
Green, sandy shale	21
Fine-grained, green sandstone	12
Green, crumbly shale in places heavily stained with iron	40
Green, shaly sandstone and shale, iron stained	27
Fine-bedded, green, shaly sandstone and some shale	36
Grey-green, shaly sandstone with some coarse, grey sandstone	27
Grey-green sandstone	17
Hard, black shale	1
Grey, shaly sandstone	14
Green sandstone and shale; contains a 4-foot bed of grey ironstone	250

Concealed	65
Green, sandy shale	15
Concealed	20
Grey-green, fine sandstone	20
Finely bedded, olive-green shale	43
Massive, grey-green sandstone	1
Green-weathering, grey, sandy shale	7
Light grey sandstone with layers of grey to black, sandy shale	10
Grey weathering, brown to black shale	7
Massive, green sandstone	10
Fine-grained, green sandstone with layers of green, sandy shale	70
Green sandstone with carbonaceous material, weathers buff	13
Compact, brown and green shales weathering red	29
Green, compact, sandy shale weathering rusty red	23
Green, shaly sandstone with ironstone concretions	10
Green, sandy shale	8
Grey to green, coarse sandstone	8
Green-grey, sandy shale	10
Fine-grained, green, sandy shale	5
Fine-grained, light buff-weathering, green sandstone	4
Green shale	29
Fine-grained, green sandstone, with ironstone concretions	8
Green weathering, black shale	8
Thin-bedded, green sandstone	4
Very compact, dark grey argillite; weathers red-brown	3
Fissile, green-weathering, grey shale	10
Coarse, green sandstone	4
Black shale with green sandstone lenses	20
Light grey, finely bedded, shaly sandstone	11
Compact, argillaceous limestone	10
Black shale	5
Concealed	69
Light grey, coarse sandstone	50
Concealed, largely green shale, 15-foot limestone bed	170
Massive, coarse, grey, cherty sandstone (Blairmore conglomerate)	20
Total thickness of formation	2,316

<u>Southernmost Alberta:</u> The Blairmore formation has not been reported as outcropping along the International

Boundary in Alberta. Daly (20) found no trace of it in his survey of the 49th parallel. As far as is known the Blairmore formation is exposed farthest south in Canada in the Flathead valley in the mountains just north of the International Boundary, where the Kootenay-Blairmore succession is exposed in an area about six miles long (79).

In the South Fork coal area, Oldman river (77), the Blairmore formation is typically developed. MacKenzie reported a 4- to 20- foot persistent limestone band, containing some fossil shells, from near the middle of the formation. A conglomerate band higher up in the formation is distinguished from the basal conglomerate, which MacKenzie placed in the Kootenay, by its greater coarseness, softness and different weathering. A thickness of 2,500 feet was reported for the formation.

Highwood Area: Rose (126) reported the Blairmore formation as being typically developed across the Highwood area. As well as the basal conglomerate, Rose reported other conglomerate bands in the formation. An Upper Cretaceous age was assigned by him to the Blairmore.

Turner Valley: For the stratigraphy of this and immediately adjacent areas reference should be made to the reports of Hume (40-47), (49-54). Knowledge of the Blairmore formation has been obtained solely from well logs. Hume (52) has

described the Blairmore as consisting of an upper part of alternating green, grey and dark shales and sandstone, and a lower part of dark shales and arenaceous, limy bands. The two parts are separated by a white or grey, granular sandstone known as the Home sand, which occurs about 900 to 1,000 feet below the top of the formation.

Several poorly defined sandstone zones are present in the upper part of the Blairmore. Of these the Stockmens and the McDougall-Segur are the most important and occur at depths of 100 feet and 200 to 400 feet respectively, below the top of the formation. The McDougall-Segur sandstone consists of sandstones separated by some shales with, in some places, a carbonaceous zone of thin coaly beds at the base. A conglomerate with pebbles of considerable size, consisting in the main of black cherts and quartzites with porphyries in minor amount, in some areas replaces part of the sandstone. A thickness of up to 200 feet has been recorded for this sand. Beneath the McDougall-Segur sand characteristic grey and greenish sandy shales and sandstones with occasional plant remains are developed. About 650 feet below the top of the formation a carbonaceous layer or coal seam, referred to by Goodman (185) as the Kootenay Coal, forms a fairly persistent marker in well samples. Between the coal and the Home sand are grey and green sandstones and shales with coal partings. A thin ironstone shell exists above the Home sand.

The lower part of the Blairmore consists of brown, limy sandstones and limestones alternating with dark shales (54). The limestone beds carry non-marine fossils. Grey and greenish shales with brown limy bands occur 40 feet, and limy sandstone 90 feet below the Home horizon. Forming the base of the formation is a conglomeratic and coarse sandstone known as the Dalhousie sand. This is the equivalent of the Blairmore conglomerate and in Turner Valley wells attains a thickness of 20 to 30 feet. The Dalhousie, Home, and McDougall-Segur sandstones are productive oil horizons, in certain areas only, in Turner Valley.

Hume reported the thickness of the Blairmore in Turner Valley as varying between 1,050 and 1,200 feet, a thickening to the north and to the west being experienced. A thickness of 1,200 to 1,500 feet was assigned to this formation in the Pekisko Hills by Hume (49).

Moose Mountain: In this area Cairnes (16) reported a thickness for the Blairmore of from 900 to 1,700 feet. The basal conglomerate is present here typically developed, and averages 10 to 30 feet in thickness. It overlies immediately the Kootenay coal measures and for this reason Cairnes referred to it as the coal conglomerate. Hume (54) reported the thickness of the Blairmore in this area as being over 2,000 feet. The formation thickens farther west behind the front range at the head

of the south branch of Sheep creek at Burns mine (165, p. 12).

Southern West-Central Alberta: Southern west-central Alberta is herein considered to extend from the Bow river to Ram river.

Rutherford (134) reported that only the upper part of the Blairmore formation is exposed on Bow river east of the front range. These beds are exposed on Kananaskis river and consist typically of alternating beds of shales, arenaceous shales, shaly sandstones and sandstones of freshwater origin. The total thickness could not be determined as only part of the formation outcrops. Hume (54) stated that the Blairmore formation may be 1,400 feet thick in the Jumpingpound area.

To the north of the Bow river in the foothills Hume (48) reported that only the upper part of the Blairmore is exposed on the west of Wildcat hills. A thickness of 2,000 feet was estimated by MacKay (76) for the Blairmore formation in the Fallentimber area. Warren (165) reported that farther north on Red Deer river east of Hunter Valley well, the basal Blairmore is exposed. The conglomerate is present, is massive and quite thick, and is underlain by the Kootenay (165, p. 13). Hume (165,p.13) reported that the conglomerate with the accompanying sandstone can be traced north to James river. Evans (38) gave a thickness of 1,902 feet for the Blairmore on Red Deer river. The conglomerate

is 24 feet thick in this section.

Warren (165) stated that at Marble Mountain on Tepee Pole creek, the Blairmore formation is exposed around the Palaeozoic fold. The conglomerate, about 35 feet in thickness, is well exposed. Due to the non-deposition of the Kootenay formation in this area, the conglomerate rests on the Fernie shale. A section on Ram river (38) shows a thickness of 2,017 feet of Blairmore strata underlain by Kootenay measures.

West-Central Alberta: West-central Alberta is herein considered to extend from the vicinity of Nordegg northwestwards to the Berland river area.

In the Nordegg area, Allan and Rutherford (3) termed what the writer in this thesis is calling the Blairmore formation, the Kootenay. They showed that the conglomerate at the base of this formation lies directly on top of the Fernie shales. The conglomerate varies in thickness from 10 to 35 feet, while the Blairmore attains a thickness of 1,500 feet with an average of about 1,000 feet for the area (165). The coal seams of this area occur near the base of the formation which is the producing horizon in this area.

Sanderson (139) reported that at Brazeau Collieries drilling was carried through at least 1,000 feet of beds which were ascribed to this formation. He described the Blairmore as

composed of interbedded dark green and dark grey carbonaceous shales and feldspathic sandstones, containing, in the upper half, several coal seams. Thin beds of dark grey and greenish chert pebbles, which Sanderson considered to correspond to the well known Grit bed of the Turner Valley section, occur near the top of the formation. He assigned a thickness to the conglomeratic, coarse sandstone member at the base of the formation of from 20 to 40 feet, and stated that it is probably the equivalent of the Dalhousie sand of the Turner Valley sequence.

To the west of Nordegg in the Bighorn coal basin Malloch (84) reported a thickness of 5,458 feet for the Kootenay-Blairmore succession. His subdivision into the two formations was not made at the conglomerate, (12 feet thick here) (84, p. 25), and resulted in a thickness of 3,659 feet for the Kootenay and 1,799 feet for the Blairmore. This is contrary to the normal thickness relationships existing between the Kootenay and Blairmore. However, were a division made at the conglomerate, 1,467 feet of strata would be referred to the Kootenay and 3,991 feet to the Blairmore. In this area the conglomerate bed is but 10 feet thick.

Allan and Rutherford (4) in continuing the work north from the Nordegg area along the Blackstone, Brazeau and Pembina rivers, used the term Kootenay for the whole Kootenay-Blairmore succession. On the basis of lithology alone, they divided it

into two members - the upper, the McLeod member, which corresponds to the upper part of the Blairmore, and the lower, the coal-bearing member which includes the Lower Blairmore, the conglomerate and the underlying sandy beds. The coal horizon is mainly in the Lower Blairmore. No good measurements of the thickness of the formation are given for this area.

In the extension of this work to Athabaska river Rutherford (132) employed the same nomenclature. For this same area along the McLeod and Athabaska rivers MacKay (68), (71), introduced a new nomenclature for the Lower Cretaceous formations. For the conglomerate bed within the area he introduced the term Cadomin conglomerate; for the coal-bearing beds above the conglomerate, Luscar, and for the barren Cretaceous beds overlying the Luscar, Mountain Park formation. MacKay (71) described the Cadomin conglomerate as a massive, resistant, light-colored conglomerate, composed of pebbles of quartzite, chert and vein quartz firmly cemented in a clean, siliceous matrix. He assigned to it a thickness of 3 to 75 feet with an average of 25 feet. The contact between the conglomerate and the underlying Nikanassin beds (Kootenay in age) in the Brule area (68) is disconformable, as evidenced by the erosion in places of some of the lower beds before the deposition of the conglomerate.

Overlying this massive conglomerate are the coal-bearing

strata of the Luscar formation. In the Brule area MacKay (68) assigned to them a thickness of 1,950± feet but said that some of the upper beds may belong to the Mountain Park sandstone. Farther south at Mountain Park, MacKay (71) assigned a thickness of 1,700 feet of soft, grey sandstones, interbedded with dark grey shales and several conglomerate lenses to this formation. This is the coal-bearing horizon of the district. It is possibly correlative with the Lower Blairmore of the southern foothills.

Overlying the Luscar formation, is a series of hard, rusty-brown weathering, coarse, cross-bedded sandstones and olive-green sandy shales, and lenses of rusty-red weathering conglomerate composed largely of small black chert pebbles (71). On Brazeau river the Mountain Park formation is 825 feet thick, but on McLeod river it is only 400 feet thick at Mountain Park, at Cadomin 330 feet thick, and at Luscar 320 feet thick. If this northward thinning of the formation continues it is likely that the Mountain Park formation is not represented as a distinct formation in the Brule area on the Athabaska. Should it be present in this latter area, MacKay stated that the beds have lost entirely their ridge-forming character and their characteristic greenish color.

In the area north of the Athabaska, MacVicar (82), (83), used the term Kootenay for all the coal-bearing beds and underlying strata down to the top of the Fernie. For the upper barren beds,

the probable equivalent of the Upper Blairmore, he introduced the term Sunset sandstone. MacVicar (83) stated that it varies in grain from fine to coarse and in places passes into a conglomerate. He ascribed a thickness of not less than 3,000 feet to the formation. Warren (165), however, believes that MacVicar may have included some overlying Belly River beds in his succession, believing them to be Upper Blairmore.

In 1932, Allan, Warren and Rutherford (5) working east of the front ranges at Jasper observed Cretaceous rocks only in the Pocahontas valley. They stated that the best correlation is with the Lower Blairmore of the Crowsnest district.

Peace River Canyon: References to strata of Blairmore age in the Peace river area are to be found in the reports of Selwyn (141), Dawson (21), Stewart (152), McLearn (93), (98), (110), (117), Spieker (147), Rutherford (136), Williams and Bocock (177), Warren and Stelck (168), and Allan and Stelck (9). McLearn in this area showed the Blairmore formation to be represented by four members. In ascending order these are as follows: Gething member of the Bullhead Mountain sandstone, Moosebar shale, Gates sandstone and St. John shale. More recent work by Warren and Stelck (168) indicated that the Dunvegan sandstone at the top of the St. John shale represents part of the Upper Blairmore time.

Gething Member of the Bullhead Mountain Sandstone:

In 1923 McLearn (98) subdivided the Bullhead Mountain sandstone into two members, the Lower member, and an upper member, the Gething member. McLearn considered the Gething member as a probable correlative of the Luscar formation and the Lower Blairmore formation of the central and southern foothills area respectivel (110, p. 167).

The Gething member, described by McLearn (98) as consisting of non-marine sandstone and shale, contains commercial coal seams. Massive, medium to fine, rarely coarse sandstones, also bedded or layered sandstones, are present. Some of the layered sandstones are ripple-marked; the finer-grained and thinner layers are cross-bedded, having wavy, cut-off, fine bands of dark grains or films of shale. Large scale cross-bedding is rare. Rootlets are present in a few sandstone beds. A few beds of argillaceous sandstone, of carbonaceous sandstone, and of micaceous sandstone are present. No coarse grits occur. The nearest approach to a conglomerate in the Gething member in the Peace River canyon is an 18-inch bed of sandstone containing small scattered pebbles, at the top of the formation. South of the Peace on Pine river a thick conglomerate zone occupies this position (117, p. 72). The coarser sandstones are light in color, white, cream, or pale

yellow, while the finer sandstones are light grey or slightly brownish. The shales, grey to black in color, are present in beds 2 inches to 10 feet thick, and break into angular fragments. The black carbonaceous shales are thin and somewhat fissile. Banded shales showing mud-cracks, and banded sandstones with ripple-marks, are common in parts of the section. Clay ironstone is present in beds 5 inches to 5 feet thick.

The thickness of the Gething is considered by McLearn (98) to be about 1,400+ feet. It is bounded above by the Moosebar shale and below by the Lower member of the Bullhead Mountain sandstone. The contact with the Lower member of the Bullhead Mountain has been drawn arbitrarily by McLearn at the horizon conglomerates and grits disappear, coarse sandstones become rare, and medium to fine sandstone, shale, clay ironstone and coal beds become common. Although the contact of the Gething with the Moosebar is lithologically abrupt, no evidence of an actual break has been observed.

McLearn (98, p. 5) has stated: "The abundance of plant remains, the absence of marine fossils, presence of rootlets, absence of boring molluscs in the wood fragments, traces of land animals - all these, taken together, suggest a non-marine origin for the strata of the Gething member."

Moosebar Shale:

In the original description by McLearn (93) of the Lower Cretaceous rocks along the Peace river in the vicinity of Hudson Hope, a subdivision of the strata into two formations was made as follows:

Lower Cretaceous (St. John formation
(Bullhead Mountain sandstone

McLearn at this time recognized three members in the St. John formation, but it was not until 1923 (98) that he named them. The nomenclature for this upper formation as now employed is as follows:

(St. John shale
(Gates sandstone
(Moosebar shale

McLearn (98) described the Moosebar shale as consisting of dark friable shale and thin bands and irregular concretions of clay ironstone. A thickness of 800± feet was assigned to it by him in 1940 (117). The formation is apparently of marine origin. The Moosebar shale was tentatively correlated by McLearn (110, p. 168) with the upper portion of both the Luscar formation and the Lower Blairmore formation, and the lower part of both the Mountain Park sandstone and the Upper Blairmore formation, of the central and southern foothills region respectively of Alberta.

Gates Sandstone:

The middle sandstone member of the original St. John

formation (93) the Gates sandstone, consists of 50 to 80 feet of massive, cross-bedded sandstone with vertical rootlets and prostrate stems. McLearn (110) considered the formation as apparently marine, but it contains no diagnostic fossils. The Gates sandstone has been tentatively correlated by McLearn (110, p. 168) with a portion of the Mountain Park sandstone and a part of the Upper Blairmore formation of the foothills belt to the south (110).

St. John Shale:

The St. John shale represents the upper shaly member of the original St. John formation of McLearn (93). Below the Gates it is comprised of thin-bedded, dark, hard, and friable shale with banded concretions of ironstone. It is generally soft and plastic, weathering to clay, and is responsible for many landslides along the Peace river. A thickness of about 1,300 feet is estimated for the member in the vicinity of Cache creek (93), at the mouth of Commotion creek (177), and along the north bank of Pine river (136). Farther east along the Smoky river the thickness is much less, Rutherford estimating a thickness of 600 feet near the town of Peace River (136). The thin, even bedding and marine fossils point to marine conditions of deposition.

To the south of the Peace river area in the Wapiti river basin, Evans and Caley (39) reported the probable existence of the Bullhead Mountain and Fort St. John (inclusive term) formations.

Dunvegan Sandstone:

Lying conformably upon and presenting a gradational boundary with the St. John shale is the sandstone and sandy shale formation known as the Dunvegan sandstone. As early as 1875 Selwyn (141) examined the formation, and in 1881 Dawson (21) applied the name Dunvegan to these "Lower sandstones and shales". In 1883 J. W. Dawson (25) described floral species collected by G. M. Dawson (21) in 1879 from this formation. The formation thickens to the west, 530 feet on Peace river and 600 feet on Pine river, being the thicknesses reported by Williams and Bocock (177) in 1932. Farther to the east in parts of the Peace River and Grande Prairie districts an account of the formation has been given by Rutherford (136).

There is a lateral lithological variation in the Dunvegan. From a study of the size of particles and fossil remains, Williams and Bocock (177) concluded that the depth and salinity of the Dunvegan sea increased from west to east and from south to north. Heavy beds of medium-grained, light-colored, cross-bedded, massive sandstones which occur in the lower 300 feet, followed by a succession of thin-bedded and arenaceous shale strata, characterize the formation in the Peace River Block. In the west and northwest portions, grits and fine conglomerates, whose coarseness increases to the west, were found. Clay-ironstone

concretions, large plant stem and tree trunk imprints and casts, ripple-markings, worm borings, and casts perhaps of vertical rootlets, all indicative of shallow water depositional conditions are common phenomena, especially in the north and northwest portions. The sands generally show carbonaceous fragments, and Williams and Bocock reported that coal seams up to 23 inches in thickness occur in different localities, and in different horizons in the formation, from very near the base to the extreme top. On Peace and Kiskatinaw rivers occurrences of lenses of limestone, probably of freshwater origin, and showing cone-in-cone structure, are reported. Calcium carbonate appears to be the dominant cementing material of the sandstone.

Bell (112, pp. 112-3) reported that: "The Dunvegan, however, is younger than any part of the Blairmore formation in the Blairmore area; for the Upper Blairmore flora was collected at the top of the Blairmore there and it is an older flora than the Dunvegan flora." In 1940 Warren and Stelck (168, p. 147) stated: "The Dunvegan sandstone is not represented in the southern foothills as a distinct formation but it undoubtedly correlates with the upper part of the Blairmore formation".

From the log of the Guardian No. 1 well in Tp. 80, R. 12, W6th, two miles east of Pouce Coupe creek, Allan and Stelck (9) indicated that the Bullhead Mountain sandstone, the Moosebar

shale, the Gates sandstone, and the St. John shale all are present in the area. These are represented respectively by thicknesses of beds of 1,998 feet, 490 feet, 140 feet, and 642 feet.

Flora and Fauna of the Blairmore

Flora of the Blairmore: The first account of the flora of the Blairmore formation was rendered in 1885 by J. W. Dawson (26) in his description of the flora of the Intermediate and Mill Creek series of southern Alberta. McLearn (92) in the Crowsnest field in 1915 collected angiosperms, abundantly from the upper 200 feet of the formation, and only extremely rarely from below. Cairnes (16) in the Moose Mountain area collected a probable Blairmore flora from the "Dakota". In this respect J. H. Sinclair (144) remarked on the probable pre-Dakota age of this flora.

Berry (11) gave the first description of the Blairmore floras as collected by McLearn. Berry (11), (12), stated that, while the Blairmore succession shows no apparent physical break, two distinct floras are present, one bearing Lower Cretaceous affinities and ranging through the lower five-sixths, the other of Upper Cretaceous (Dakota) age present in the upper one-sixth (200 to 400 feet).

The most noteworthy distinction between the Kootenay and Lower Blairmore flora is, as pointed out by Berry, the sparing

representation of dicotyledons in the latter and their absence in the former, the particular species, Sapindopsis brevifolia being common to the late Lower and the earliest Upper Cretaceous. Of the Lower Blairmore floras only four species with an outside distribution and not known from the Kootenay have been determined. These are: Sagenopteris mantelli, Nilsonia densinerve, Torreya dicksoniana, and Sapindopsis brevifolia.

The exact correlation of the Lower Blairmore flora is limited below by the supposed Barremian age of the Kootenay, and above by the Cenomanian age of the succeeding Upper Blairmore flora. Berry favors an age of the Lower Blairmore flora as representing the later part of Aptian and all of Albian time. McLearn (110) however, stated that it is pre-Albian in age for it underlies stratigraphically the Albian Gastroplites fauna.

Because of the neither extensive nor varied nature of the flora of the Upper Blairmore, coupled with its generally poor preservation, exact determination and correlation have been difficult. Berry (12) considers Pseudocycas unjiga as one of the most abundant and characteristic fossils in the Upper Blairmore. This species was first recorded by Dawson from the Dunvegan sandstone and is also represented in the supposed Dakota sandstone of the United States. Because of its very close similarity to Diconites buckianus abietinus which occurs in the Lower Blairmore and Lower Cretaceous horizons elsewhere, its use as a good field

index fossil is limited. Berry considers this species an undoubted member of the true Dakota flora.

The Upper Blairmore flora is quite distinct from that of the Lower Blairmore, this difference resting not only in the number and variety of dicotyledonous leaves in the former, but also on the fact that none of the ferns, cycadophytes, or conifers of the two horizons is certainly identical.

Berry considered the Upper Blairmore flora to represent an age somewhat older than that of the true Dakota sandstone but still unquestionably of Upper Cretaceous age. In terms of the standard European nomenclature, Berry would thus assign a Cenomanian age to the Upper Blairmore, while the true Dakota would be Turonian in age, and represent the transgressing littoral of the Benton sea.

McLearn however, suggested that the Upper Blairmore flora "would be dated at least as early as Albian or late Lower Cretaceous by some palaeontologists, as it is followed stratigraphically by a marine fauna which most would interpret as late Albian" (110, pp. 161-2). On this basis then the boundary between the Lower and Upper Cretaceous would fall at the top of the Blairmore formation in the Blairmore area, and not within it as suggested by Berry.

Flora of the Correlative Beds of the Blairmore Formation: Bell (68) determined the flora of the Luscar formation

to be a Lower Blairmore flora. His conclusion was based on the finding of four species which he considered to be typical Lower Blairmore forms. These are: Marchantites blairmorensis, Cladophlebis distans, Sagenopteris mclearni and Athrotaxopsis grandis.

MacVicar (83) reported the identification by Knowlton of Zamites acutipennis Heer in conjunction with the marine genus Tancredia from the Lower Blairmore (Luscar) formation in the Smoky River basin near Grand Cache lakes. The specimens were found in association with an 8-foot thick coal seam.

Allan, Warren and Rutherford (5) reported beds in the Pocahontas valley which contain flora most closely related to the Lower Blairmore flora. Their flora included Cladophlebis sp., Ginkgoites arcticus (Heer), Ptilophyllum dunkerianum (Geoppert), and Athrotaxopsis grandis Fontaine.

To the northwest the Gething member of the Bullhead Mountain sandstone contains the widely spread foothills flora, the Lower Blairmore flora (110). McLearn (93) found, and tentatively so identified this flora in 1918. Confirmation of this determination was made later by Berry (11), and by Bell (110, p.165). On this basis McLearn correlated the Gething member with the Luscar and Lower Blairmore beds of the foothills of central and southern Alberta.

The following flora included in the Gething member were identified by Berry and their age placed as Kootenay, Lower Blairmore, or Bullhead Mountain (177, p. 209), Onychiopsis sp., Torreya dicksoniana, Athrotaxopsis grandis, Sphenolepsis sp., Podozamites lanceolatus, Pterophyllum acutipennis (Heer), Berry, Athrotaxopsis grandis (cone), Oleandridra graminaefolia Knowlton, Baiera palmata, Ginkgo siberia or arctica.

Berry (11) mentioned the Gates sandstone as containing plant remains. Spieker (147) in 1922 reported from the Dunvegan a floral assemblage bearing affinities to the Dakota flora. His species included: Protophyllum lecontianum Lesquereux, Platanus latior subintigrefolia (Lesq.) Knowlton, Menispermites reniformis Dawson?, Aspidophyllum trilobatum Lesquereux, Pseudocycas unjiga (Dawson) Berry, Platanus sp., and Taxodium sp. Berry (11) and Bell (177) have also reported on the flora of the Dunvegan.

Fauna of the Blairmore: From the Blairmore formation of the Crowsnest region McLearn (104) reported a few freshwater invertebrates, in the main poorly preserved. The lowest known fossiliferous horizon is about 230 feet above the base of the formation, on Lyon creek, where a bed of fossiliferous, yellow-weathering, conglomeratic sandstone contains Unio natosini, ~~and~~ Unio cf. hamili. and Unio sp. This fauna forms the Unio hamili fauna, a non-marine invertebrate fauna. About 520 feet above the

base of the formation and also on Lyon creek fossils are found in two layers between two thick calcareous beds. The lower layer consisting of shale and argillaceous limestone contains indeterminate Corbula? young Unio?, and Planorbis. The higher layer is of dark shale and carries ostracods, indeterminate young Unio and Campeloma?

McLearn (164) stated that the highest known invertebrates occur at a horizon about 310 feet below the top of the formation, or approximately 1,540 feet above the base, in dark shales on Castle river, a little above the mouth of Link creek. The species Unio douglassi, is found also at this horizon, This uppermost known invertebrate-bearing bed is 230 feet below an occurrence of the upper or dicotyledonous angiosperm flora and 175 feet above the highest known occurrence, in this section, of the lower or primitive flora, with very rare dicotyledonous angiosperms.

To the north of this area in the Moose Mountain district Cairnes (15) reported an invertebrate fauna from the Blairmore formation, and Malloch (84, p. 44) reported the Astarte fauna from the Bighorn coal basin. McLearn (110) stated that MacKay reported a poorly preserved, in part at least marine, fauna containing "Astarte" natosini from beds in a faulted area on Thornton creek, and which MacKay considered as belonging to the

lower part of the Luscar formation.

In northern west-central Alberta the Blairmore formation contains five marine or partly marine faunas, the late Barremian or early Aptian "Astarte" natosini fauna, the Aptian Beudanticeras affine - Deshayesites fauna, the early Albian Gastroplites fauna, the later Albian Neogastroplites fauna (110) and the Upper Cenomanian Dunveganoceras fauna (168).

The Dunveganoceras fauna has been found in the upper 200 feet of the Dunvegan sandstone and in the basal beds of the Smoky River shales. The fauna includes the genus Dunveganoceras.

The Neogastroplites fauna (108) occurs 100 or 150 feet below the Dunvegan contact near the top of the St. John shale and includes Neogastroplites cornutum (Whiteaves), other species of Neogastroplites, Nucula dowlingi McLearn, and Inoceramus nahwisi McLearn.

The Gastroplites fauna (106) in the Peace River canyon comprises Gastroplites kingi McLearn, Inoceramus cf. cadottensis McLearn, Panopaea sp., and a starfish. This fauna occurs about 1,000 feet above the Gething member (117) and according to McLearn (111) is found in the lower part of the St. John shale. C.R. Stelck*, however, has collected Gastroplites from strata below the St. John.

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* Unpublished Master's thesis, University of Alberta.

McLearn (108) reported that the Beudanticeras affine fauna is unknown in the Peace River canyon section. The lowermost fauna - the "Astarte" natosini fauna - is a brackish or a marine fauna found in the lower part of the Luscar formation. It includes "Astarte" natosini McLearn.

From the Gething member of the Bullhead Mountain sandstone McLearn (177, p. 210) identified the following fauna: Aucella?, Pleuromya? and a small belemnite. C. M. Sternberg (177, p. 210) has described the dinosaur tracks discovered by McLearn in the coal-bearing or lower portion of this member. These are as follows: Irenesaur ipas mclearni, Irenesauripas occidentalis, Irenesauripas acutis, Columbosauripas ungulatus, Gypsichnites pacenis, Amblydactylus gethingi, Tetrapodosaurus borealis and Irenichnites gracilis.

A representative fauna of the Dunvegan, taken from reports of McLearn (97), (112), Rutherford (136) and Warren and Stelck (168) in which the diagnostic forms are listed, follows: Unio dowlingi McLearn, Brachydontes multilinigerus Meek, Mactra emmonsi Meek, Corbula pyriformis Meek, Ostrea soleniscus Meek, Tellina dunveganensis McLearn, Inoceramus dunveganensis McLearn, Barbatia micronema (Meek).

The presence of Dunveganoceras cf. albertense Warren in the upper beds of the Dunvegan sandstone permits an Upper Cenomanian age to be assigned to the upper part of this formation. The

lower contact of the Dunvegan with the St. John shale of Albian age has not been accurately placed. It follows, however, that Lower Cenomanian time is represented somewhere in the lower part of the Dunvegan or the uppermost part of the St. John.

Complete synchronism between the Blairmore flora and fauna is not yet possible. However, as two of the marine faunas of the northern section have been found in the western foothills, flora-bearing sections, some attempt at showing inter-relationships of the flora and fauna has been made. McLearn (110) contended that the "Astarte" natosini fauna appears to be coeval with the Lower Blairmore flora in a part of its time range at least; while the Gastroplites fauna in the northwest section occurs at a horizon considerably higher than the Lower Blairmore flora. He showed that this flora is likely of pre-Albian age at least.

6. Crowsnest Volcanics - Upper Cretaceous

As far as is known the Crowsnest Volcanics represent the only igneous rock occurrence in the foothills and front ranges of the Rocky Mountains. It was G. M. Dawson (24) who first noted their presence in 1881. In 1902 Leach (62) mapped the formation and submitted a collection of specimens to C. W. Knight

for petrographic descriptions. In 1912 Leach (63) assigned a thickness of 1,150 feet to the volcanics west of Coleman, while to the east at a point about 2½ miles west of Blairmore, they have thinned to 440 feet. Their presence was noted by MacKenzie (77) in the South Fork coal area in 1912. Two years later this same author prepared a paper on the Crowsnest volcanics (78). Later reference has been made to them by Rose (123), (125), (126), MacKay (73), (74), and Rutherford (137).

The Crowsnest Volcanics are known to outcrop as far south as latitude 49°25' and to the north as far as latitude 50°5'. In their northern extension they lie completely to the west of the Livingstone range, while to the south their projected areal outcrop widens somewhat to about fourteen miles. The area in which outcrops are known to occur is about 550 square miles. A former greater areal distribution has been assumed. Because of their hardness and resistance to erosion they assume definite topographic expression.

The volcanics attain their maximum thickness about two miles east of Crowsnest mountain, and for this reason the centre of eruption has been assumed to lie in this area. From here they thin rapidly to the east, and somewhat less rapidly to the north, south, and probably to the west. Leach and MacKenzie agreed that the former extension of the volcanics was not over ten miles west

of Crowsnest mountain. MacKay (73) assigned to them a thickness of 600 feet in the east part of the Crowsnest region and 1,800 feet in the west at Coleman. The volcanics have thinned to about 1,300 feet about six miles south of Coleman (74).

The Crowsnest Volcanics are a series of tuffs and agglomerates, with flow rocks. Rose (123) stated that they vary in texture from ash-fine tuffs to coarse agglomerates with fragments of up to 2 and 3 feet in diameter, and that a color range from light grey to green, pink and purple is exhibited. MacKay (74, p. 240) in 1934 described the Crowsnest volcanics as consisting of "waterlaid, thin-bedded, dark grey ash beds which grade upward into coarse, massive, olive-green tuffs with bombs up to a foot or more in diameter, followed by agglomerates and flow breccias interstratified with waterlaid ash. The tops of some of the flows are characterized by a profusion of phenocrysts of pink feldspar ranging up to dimensions of $1\frac{1}{2}$ inches by $\frac{1}{2}$ inch and others with large crystals of primary analcite. At some horizons, there are large, included fragments of a dark green rock having a uniformly textured groundmass with amygdules filled with analcite, leucite, and other zeolites." In places the volcanics are high in magnetite. Distinct drag folds are evident in places in the flow rocks.

Rutherford (137, p. 67) reported that from a locality about 1½ miles west of Coleman the following general sequence, in descending order, prevails:

(1) Ash beds with varying amounts of coarse pyroclastics.
(2) Beds rich in analcite.
(3) Ash beds containing numerous fragments and some large pieces of pyroclastics.
(4) Trachytic beds rich in feldspar phenocrysts with some bands of coarse pyroclastics.
(5) Trachytic beds rich in melanite garnet.

Rock types as determined by Knight were: augite, trachyte, tinguaite, andesite and analcite trachyte; while MacKenzie determined the following: aegirite-augite trachyte, melanite-bearing trachyte, latite, and blairmorite (analcite rich). (123).

The volcanics generally are stratified and clearly waterlaid deposits in part. MacKay (73) reported that they are largely non-marine. Thin beds prevail; beds over 10 feet in thickness are rare.

The Crowsnest Volcanics appear to be underlain conformably by the Blairmore formation, and are apparently overlain conformably by the Alberta shale. Both contacts are of a gradational nature. The sandstones of the Blairmore formation generally become coarser as they approach the Crowsnest Volcanics and then pass by the introduction of tuffaceous material into the volcanics. At their upper limit the volcanics usually become finer and thinner bedded as they approach the contact with the Alberta shale. This upper contact is usually obscured by detritus.

Webb (169, p. 1390) considered the volcanics as "simply an areally developed facies of the upper part of the Blairmore formation."

As yet but a very poor specimen of a leaf is the only fossil remains found in the volcanics (104, p. 105). The Crowsnest Volcanics must, however, be considered on present evidence to be of Upper Cretaceous age, for they overlie beds containing a flora which may be as old as Albian or as young as Cenomanian, and underlie beds containing a Turonian fauna. On this basis they must be Cenomanian or early Turonian in age.

7. Alberta Shale - Upper Cretaceous

Introduction

The Alberta shale, chiefly a marine sequence of Colorado and Lower Montana age lying between two series of freshwater deposits, forms a considerable part of the bedrock in the foothills region of Alberta. Faulting and folding associated with orogenic movements to the west have brought the formation to the surface in numerous belts. The formation is known by various names in the area under discussion, but the writer considers the term Alberta shale to be most adequate.

Previous Work

The name Alberta shale was first proposed in 1930 by Hume (44, p. 6) "for the series of marine shales mostly Colorado and Montana in age occurring in Turner Valley and adjoining areas between the Blairmore and Belly River formation." The term Benton which previously had most commonly been employed when reference to this formation was made, was a misnomer for it represents only the lower division of the Colorado. Nor could the term Colorado shale be used with propriety, for in its definition by Eldridge (148) it was restricted to the Fort Benton and Niobrara of Meek and Hayden and included no beds of Montana age. As a few hundred feet of lower Pierre shales of Montana age are present in the so-called Colorado shale of the southwestern Alberta area, Hume proposed the new formational name Alberta shale to include these beds of Colorado and Montana age. At this time a division was made into two shale members, the Lower Alberta shale and the Upper Alberta shale, separated by a thin sandstone, the Cardium member.

Early reference in the southern area to strata which we now term Alberta include McConnell (87), Leach (62), (63), MacKenzie (77), Cairnes (15), (16), McLearn (91), Rose (126), Stewart (151) and Slipper (36), (145), (146). In 1927 Hume (41) referred the whole sequence to the "Benton" formation. Rutherford (134) in 1927 established the terms Lower Benton, Cardium and Upper

Benton, and in this respect was followed by Hume (42). Later references to the Alberta shale are to be found in the reports of Hume (45-54).

The section in west-central Alberta has been reported on by Malloch (84), Allan and Rutherford (3), (4), Rutherford (132), MacKay (71), Warren and Rutherford (156), Webb and Hertlein (169) and Sanderson (139). MacVicar (83) has discussed the Smoky, Hay and Berland river areas, and Evans and Caley (39) the Wapiti river basin. To the northwest of this area in the vicinity of the Peace river, the equivalents of the Alberta shale have been reported on by Dawson (21), McConnell (88), McLearn (100), (102), (104), Rutherford (136), Williams and Bocock (177), Warren (159), (162), (191), and Warren and Stelck (168).

Lithology, Distribution, Thickness

General Statement: The Alberta shale or its equivalents, are known to extend for approximately 350 miles in a northwesterly direction from the International Boundary in southwestern Alberta, to the vicinity of the Peace river. Throughout much of the area the formation outcrops, but owing to its non-resistant character it has weathered readily and good exposures of the formation are consequently few. However, the Cardium or Bighorn member, being more resistant to erosion, has commonly

found topographic expression as ridges, and for this reason its value as a stratigraphic marker is important.

The Alberta shale consists in the main of grey to black marine shales, sometimes quite fissile and containing clay ironstone nodules. A bed of sandstone is generally present within the formation and has been used to divide the formation into Upper and Lower members. In the south a thickness of about 2,700 feet was reported from the Turner Valley area, while to the north in the vicinity of the Peace river, the formation has thinned out to about half this amount. For the standard European nomenclature of the Cretaceous reference should be made to page 59 of this thesis.

Turner Valley - The Type Section: While good exposures of the formation are infrequent anywhere in the area under consideration, the Alberta shale has probably been studied most closely in the Turner Valley area. It was here that Hume (44, p. 6) first introduced the term for these marine beds of Colorado and Lower Montana age.

Lower Alberta Shale:

Hume (52), (54), described this lower member as consisting of dark grey to black shale with thinly laminated cross-bedded, sandy beds. It is typically marine in origin. At the base of the formation is a fairly coarse, quartzitic sandstone

known as the "grit". Fish scales and bones occur plentifully in the "grit" in some localities. Hume stated that in many places there are a few feet of dark shales below the "grit", so that while the "grit" is generally considered as marking the contact with the underlying beds of the Blairmore, it in many places is actually within the Alberta shales. One rather coarse and gritty sandstone member, known as the Jumpingpound sand, occurs about 300 feet above the base. It is a very persistent horizon, although somewhat poorly defined as it grades into the underlying and overlying shales. In Turner Valley the Lower Alberta shale attains a thickness of from 800 to 900 feet. A slight northward thickening of the formation occurs but Hume doubts that the formation is more than 900 feet thick in the Jumpingpound area. The lower contact of the marine Alberta shale with the underlying typically fresh-water deposits of the Blairmore formation is abrupt, without any indication of an intervening period of transition from a totally continental to a wholly marine environment. The upper contact of the Lower Alberta shale with the overlying Cardium member is generally of a gradational nature, and is therefore arbitrarily drawn at the base of the lowest sandstone band in this transition zone.

Cardium Member:

The term Cardium sandstone was introduced by Cairnes

(15, p. 29) in 1907. In Turner Valley the Cardium consists of 30 to 40 feet of grey sandstone and sandy shale (54, p. 2). About 150 feet above the Cardium is a 2-inch pebble-bearing zone, while 100 feet below it another similar pebble band occurs. The pebbles of both zones are of blue, green, and black chert and quartzite, generally well-rounded. Rutherford (134) stated that the average size of pebble was from 1/4 to $\frac{1}{2}$ inch in diameter. To the west these pebble zones become conglomerates at the top of sandstone members and there the Cardium is considered as embracing the conglomerate bands and all intervening strata (54). A thickness of 250 to 300 feet is reported from the west. In the Wildcat Hills area Hume (48) assigned 350 feet of beds to this member. Hume (44) suggested the possibility that the individual bands of the Cardium do not everywhere occupy the same stratigraphic position.

Slipper (146) in 1921 did not recognize the Cardium in the Sheep river (Turner Valley) area. He mentioned, however, a sandstone horizon of irregular composition and distribution occurring about 700 feet above the base of the Alberta shale. This member which undoubtedly is the Cardium, he designated the Lineham member.

The contact of the Cardium and the overlying Upper Alberta shale is transitional, although some authors (169, p. 1398) state that it is sharply defined. The top sandstone or conglomerate

of the Cardium member is directly overlain by the fine-grained dark grey shale of the basal Upper Alberta shale. In some areas a thin band of nodular brown-weathering ironstone marks the contact. The relationship existing at the lower boundary of the Cardium is one of conformity and gradational change.

Upper Alberta Shale:

Hume (54, p. 2) described this member as consisting of shale and sandy shale of marine origin. In the upper part of the member is a yellow-weathering sandstone termed, in Turner Valley only, the Highwood sandstone. In the eastern foothills areas as much as 300 feet of grey, sandy, marine shales separate this sandstone from the Belly River formation. It is thin or even absent in some eastern areas but westward thickens rapidly. In many places it becomes conglomeratic and indistinguishable from Belly River strata. In an exposure on Highwood river Hume (52, p.5) reported this sandstone as being at least 35 feet thick and capped by a thin conglomerate holding greenish grey and black chert and quartzite pebbles. Hume assigned a thickness of 1,700 to 1,800 for the Upper Alberta shale in the Turner Valley area, and stated that a very slight northward thickening to Bow river is probable.

The upper 200 to 300 feet of this member contains Baculites ovatus and is therefore Montana in age; the remainder carries the Scaphites ventricosus fauna of Colorado age. The

lower contact of the Upper Alberta shale is transitional, although it has been reported (169, p. 1398) as sharply defined. The upper contact, however, is gradational into the freshwater strata of the Belly River formation of Montana age.

Warren and Rutherford (156) stated that while the Upper and Lower Alberta shales are very similar lithologically, the Lower Alberta shales are usually less arenaceous, more fissile, and freer from ironstone nodules than those of the upper member. Hume (54) considered that the combined thickness of the three members of the Alberta shale in the Turner Valley area, is at least 2,700 feet.

Southern Alberta: In 1912 Leach (63) referred a series of shales overlying the Crowsnest volcanics and including at least two sandstone members, to the Benton, with a possible Niobrara age for the rocks towards the top. His lower sandstone bed, about 12 feet in thickness, consisting of dark colored, thin-bedded sandstone, often showing ripple-marks, is separated from the base of the formation by about 250 feet of dark grey fissile shale with a few thin arenaceous beds. About 220 feet above the lower sandstone bed and separated from it by somewhat sandy, rusty-weathering shales containing a few clay ironstone nodules, is the upper sandstone bed, a very siliceous hard sandstone generally dark grey on fresh fractures and weathering to light tints. This sandstone is generally 15 to 20 feet thick and because

of its hardness and persistent character forms an excellent horizon marker. Above this latter sandstone bed are 150 feet of sandy shales and shaly sandstones followed by dark rusty-weathering sandy shales and grey nodular clay shales. Because the whole succession weathers readily exposures are few. This, coupled with minor folding and crumpling, makes a thickness determination only approximate. Leach recorded 2,750 feet of beds and added that several hundred feet more may be present. His best sections are on York and Pelletier creeks. Rose (123) in 1917 mentioned these same two sandstone layers. His section on York creek measured 3,245 feet.

To the east in the South Fork coal area, MacKenzie (77) reported a thickness of probably not less than 2,000 feet for the Alberta shale, which, in this area, is typically developed. He reported a bed of very hard, fine- to medium-grained quartzose sandstone, ordinarily 10 to 20 feet thick, but in the vicinity of north Kootenay pass 150 feet thick, near the top of the lower third of the sequence. This probably represents the Cardium. Above this hard band the measures are more arenaceous. Stewart (151) in 1919 reported that the Cardium beds are not well represented along the eastern edge of the foothills of the disturbed belt of southwestern Alberta.

A thickness of 3,250 feet was reported for the Alberta

shale at Blairmore by MacKay (72) in 1932. In the following year (73) he mentioned the presence of the two hard, resistant quartzitic sandstone bands as described by Leach, and stated that they probably represent the Cardium bands of areas farther north. At this time MacKay reported a thickness of 3,000 feet for the Alberta shale in the eastern part of the Crowsnest pass.

Webb and Hertlein (169) in 1934 reported a thickness for the Alberta shale of nearly 2,000 feet in the area about Mill creek. Of this thickness the Upper Alberta shale is represented by about 1,500 feet of beds, the Cardium by only about 33 feet and the Lower Alberta shale by 450 feet. In the Crowsnest river valley east of Coleman, the Cardium member is represented by 33 feet of interbedded hard sandstones and sandy shales, with a 2-inch layer of chert pebble conglomerate at the top, whereas south of Crowsnest river the Cardium is generally 10 to 15 feet thick, and is entirely lacking at one locality on Castle river (169, p. 1398).

On Oldman and Castle river in 50 feet of comparatively soft, sandy shale in the basal part of the Upper Alberta shale, numerous bentonite seams and associated volcanic ash lenses occur (169). About 225 feet above the bentonite and ash horizon on Oldman river are a few thin, hard sandstone bands. Webb and Hertlein (169) stated that these beds are possibly equivalent to the uppermost Cardium sandstone band of the region to the north.

In the Crowsnest pass area the Alberta shale lies conformably upon the Crowsnest volcanics and in turn is overlain transitionally by the freshwater measures of the Allison formation (169).

Bow River Area: North from Turner Valley the Alberta shale has been reported by Rutherford (134) along the Bow river. He mentioned the presence within the Upper Alberta shale of zones, of no definite stratigraphic position, carrying ironstone nodules. The nodules average 6 to 12 inches in diameter and weather to a reddish-brown color. Hume and Hage reported its occurrence in the Jumpingpound (44) and Wildcat Hills (48), (40), areas northwest of Calgary. In the Ghost river area sections of the Alberta shale, in some cases composite in nature, have been prepared by Webb and Hertlein (169).

Fallentimber Area: In the Fallentimber area MacKay (76) reported that only the upper part of the Wapiabi formation consisting essentially of thin-bedded, fissile, and black marine shales, is exposed. Greenish, sandy shales containing numerous bands of sandstone, and of ironstone generally less than an inch thick, comprise the uppermost part, while underlying these upper arenaceous shales are dark grey and black, massive shales, which contain only an occasional ironstone concretion or a few thin, yellowish grey, argillaceous limestone bands, some of which hold an Ostrea fauna. The contact between the Wapiabi

shales and the overlying freshwater massive sandstones of the Belly River formation is clearly defined on Red Deer river and Fallentimber creek, but on Little Red Deer river a transition zone about 100 feet thick of interbedded massive shale beds and freshwater sandstones exists. Here the lower contact of the Belly River formation was drawn by MacKay at the base of the lowest sandstone bed.

West-Central Alberta: West-central Alberta is herein considered to extend from the Bow river northwestwards to the vicinity of the Berland river.

Malloch (84) originally introduced the terms Blackstone shales, Bighorn formation and Wapiabi shales in the Bighorn basin, for the members which we now in southern Alberta term the Lower Alberta shale, Cardium member, and Upper Alberta shale.

Malloch's divisions have been found to extend throughout the foothills belt between the Ghost and Athabaska rivers. Numerous sections were measured by Evans (38) in the region between the Bow and North Saskatchewan rivers. Allan and Rutherford have reported upon the Blackstone, Bighorn and Wapiabi members from the foothills belt along Saunders creek (3) and along the Blackstone, Brazeau and Pembina rivers (4). The members have been described between the McLeod and Athabaska rivers by Rutherford (132) in the Brazeau area by Sanderson (139), and in the Jasper Park area by

MacKay (71). Sanderson (139), however, employed a somewhat different nomenclature, and used the terms Lower Colorado shale, Bighorn (Cardium) sandstone, Upper Alberta shale, and Brazeau-Pierre formation for this sequence. Throughout all these areas the members exhibit a decided similarity in lithology (156),(169).

Blackstone Shales:

The Blackstone member has been described (156),(71), as consisting of black and green fissile marine shales with lenses and thin beds, (usually less than 1 foot thick), of impure limestone and iron carbonate concretions. On the whole, however, the member is remarkably homogeneous in character. Malloch (84) assigned a thickness of 1,050 feet to these beds but his section was incomplete. A thickness of 1,700 feet was reported by MacKay (71) in the Jasper Park area, 900 to 1,000 feet by Sanderson (139) in the Brazeau area, and 1,200 to 1,700 feet by Allan and Rutherford (8, p. 33). Repetition of strata through faulting makes thickness determinations only approximate. To the north in the Brule lake region (68), the Blackstone member is 1,700 feet thick and is the youngest bedrock of the area. The Blackstone is in the main Turonian (156), (169), with a Cenomanian age for the basal part (168).

Bighorn Member:

The Bighorn member is largely marine in origin but some freshwater beds are present. Lithologically, it has been

described variously by different workers in the area. MacKay (71) reported that in the vicinity of Jasper Park it consists of 350 feet of alternating brown-weathering grey sandstone and dark green to black shale, and lenses of chert conglomerate, with thin local occurrences of coal seams. Warren and Rutherford (156) described it as being comprised essentially of fine-grained sandstone, shaly sandstones, and bands of conglomeratic sandstones, while Sanderson (139) in the Brazeau area stated that it is a clean, fine-grained, quartz sand member varying in thickness from 210 to 255 feet. The thickness as reported by Allan and Rutherford (8, p. 31) is 250 to 350 feet. An Emscherian age has been assigned to the Bighorn (156, p. 33), (169, p. 1407).

Wapiabi Shales:

The Wapiabi shales conformably overlie the Bighorn member and consist of a series of black marine shales and thin calcareous beds, some layers of which contain large ironstone concretions (156), (71). The presence of these concretions serves to differentiate the Wapiabi and Blackstone shales, concretions being notably absent in the Blackstone shales except for a few in the transition zone at the top of the member. North of Brazeau river in the McLeod river area, a prominent sandstone very similar to the Highwood sandstone, occurs towards the top of the Wapiabi (169, p. 1403). Thicknesses reported for the formation vary considerably. Sanderson (139) assigned 1,400 feet of beds to the

formation on Chungo creek, Webb and Hertlein (169) 1,500 feet in the Brazeau area, MacKay (71) 1,700 feet in the Jasper Park area, Allan and Rutherford (8, p. 31) 1,500 to 2,000 feet and Warren and Rutherford (156) 2,000 to 2,300 feet. Sanderson's measurement, however, does not include a 500-foot series at the top for which he has proposed the name Brazeau-Pierre formation. These are the marine strata of Lower Montana (Pierre) age which previously have been included at the top of the Alberta shale. Generally speaking, however, the Wapiabi shale is represented by an almost equal thickness of similar beds on the Bow river. In terms of the European nomenclature the lower part of the Wapiabi is Emscherian (Upper Colorado) in age, wheras the upper 200 to 300 feet are referrable to the Santonian (early Montana) (156,p.33), (162), (169), (131, p. 26).

Berland River Area:

MacVicar (83) in 1924 introduced a new set of formational names for his section in this area. Some ambiguity as to the meaning of MacVicar's terms has arisen. MacKay interpreted the Berland River shales as the equivalent of the Blackstone, Bighorn and Wapiabi members, while Allan and Rutherford considered that the term Berland River was used only for the beds equivalent to the Blackstone member (8). This latter interpretation was upheld by Webb and Hertlein (169), who concluded that MacVicar's terms

Berland River shales and Upper sandstones and shales were assigned to strata which are undoubtedly the Blackstone, Bighorn and Wapiabi members respectively. The writer finds great difficulty in attempting to correlate MacVicar's formations, with formations or members thereof in other parts of northern west-central and west-central Alberta. He is inclined to agree, however, with the interpretation of MacKay, in so far as the Berland River is considered the equivalent of the Blackstone, Bighorn and Wapiabi members. However, it is here suggested that MacVicar possibly erred in considering the Upper sandstones and shales as a member distinct from the Berland River shale, and that these Upper sandstones and shales may represent a duplication of the upper part of the Berland River represented by the Bighorn and Wapiabi. This would account for the unusually great thickness of MacVicar's section. The 75- to 100-foot thick sandstone bed mentioned by MacVicar as dividing the formation in some places, may thus represent the equivalent of the Bighorn sandstone.

Northern West-Central Alberta: In the present discussion northern west-central Alberta is considered as the area between the Smoky and Peace rivers.

In northern west-central Alberta the Smoky River shales are considered to be directly correlative with the Alberta shale of the southern foothills area (168). Dawson first referred to this

formation as the "upper dark shales", and in 1881 (21) he applied the formational name Smoky River shales to the argillaceous strata exposed on Smoky River. In 1919 McLearn (94) subdivided this formation on the basis of lithology into three members, namely, the Upper shale, the Badheart sandstone, and the Lower shale. On fossil evidence, he grouped together the lower two members. The name Kaskapau was assigned by McLearn (100) in 1926 to the Lower shale member. The Smoky River formation was reported by Evans and Caley (39) in 1930 from the Wapiti river basin. The total thickness of the Smoky River shales in the vicinity of the Peace and Smoky rivers is somewhat less than 1,000 feet (136). Slumping of the formation is common, due to the non-resistant character of the shales.

Kaskapau Member:

The Lower Smoky River shale or Kaskapau member is generously exposed in the valleys of the streams tributary to the Peace and Smoky rivers. Rutherford (136) reported the lowest beds of this member as being exposed along the Peace and Smoky and tributary streams, while the best exposures of the upper beds occur along the Smoky river for some distance below the mouth of the Bad Heart river. McLearn (100) described the member as consisting of friable dark shales at the very base with dark, rather fissile, carbonaceous shale forming the lower half of the member.

Friable dark shales with concretions occur in the upper part, and at the very top, just below the Badheart sandstone, thin-bedded sandstones and shales are present. Rutherford (136) reported the presence of some thin, fine-grained sandstone beds in the lower strata, which apparently were absent from McLearn's section. The concretions, as mentioned above, are of ironstone or are pyritic in nature. Decomposition of the pyritic content of the shales gives rise to vapors which, on condensation at the surface, leave incrustations of crystalline salts (136). McLearn (100) assigned a combined thickness of 550 feet for the Kaskapau and Badheart members on Smoky river. Rutherford, however, assigned 850 to 875 feet of beds to the Kaskapau, claiming that if the thickness were less, the Smoky River formation would show, contrary to normal conditions, a thinning to the west. The lowermost Kaskapau is Cenomanian in age, but in the main the Kaskapau is of Turonian age (168).

Badheart Sandstone:

Rutherford (136) described the Badheart as a medium to coarse-grained porous sandstone, which is dark red in all exposures observed. The red color is apparently inherent and not the result of recent oxidation. The sandstone beds average 1 to 5 feet in thickness, and are intercalated with thin arenaceous shale beds. Occasional bands of chert and old worm borings were observed. The

thickness of the Badheart varies from 5 to 25 feet (100). Exposures of this sandstone member are best observed along the Smoky and its tributaries in the vicinity of the mouth of the Bad Heart and down the Smoky to near the mouth of the Little Smoky. The Badheart sandstone cannot be correlated with the Bighorn or Cardium members of the areas to the south. It occupies a position stratigraphically higher than these other two members. The Badheart is referrable to the Emscherian (168).

Upper Smoky River Shale:

The Upper Smoky River shale represents the last invasion of the Cretaceous sea into this area. As far as is known no seaway ever again entered this region. Essentially dark colored, thin-bedded marine shales, with a few thin sandstone bands in the uppermost beds, comprise the Upper Smoky River shale (136). A lithologic similarity between the Upper and Lower shale members of the Smoky River exists, but clay ironstone nodules are a more conspicuous element of the Lower member. The average thickness of this Upper shale member is 300 to 350 feet. At the top of the member a rather abrupt gradation into the freshwater deposits of the overlying Wapiti formation occurs. The Upper Smoky River shale is Santonian (Montana) in age and can be correlated with Sanderson's Brazeau-Pierre formation, with the Upper Wapiabi and with the upper part of the Upper Alberta shale.

Palaeontology of the Alberta Shale

Faunal Zones: Fossils from the Alberta shale have been recorded from an early date by McConnell (88), Malloch (84), Leach (63), Cairnes (16), McLearn (91), Rose (123), and Stewart (151). Because the correspondence between the lithologic and faunal zones is limited, zoning of the Alberta shale has been difficult. Zoning was attempted first by McLearn (94) on the Smoky river in 1918. At this time he recognized three local zones, one with Prionotropis and Inoceramus labiatus, one with Inoceramus umbonatus and one with Scaphites ventricosus. Rutherford's (132) succession in the foothills between McLeod and Athabaska rivers included, in ascending order, a zone with Prionotropis and Inoceramus labiatus, one with Cardium pauperculum and Inoceramus n. sp., one with Scaphites ventricosus and one with Baculites ovatus. McLearn (102) in 1927 recognized four faunas of general distribution. In ascending order these are: Inoceramus labiatus?, Prionotropis, Scaphites ventricosus, and Inoceramus lundbreckensis. In 1928 Warren and Rutherford (156) set forth the following four faunal zones of general application: The Inoceramus labiatus, Prionotropis, Scaphites ventricosus, and Baculites ovatus zones. At the base of the Alberta shale below the Inoceramus labiatus zone, they placed a Barren zone which contains fish scales (including Ichthyodectes sp.) and Inoceramus corpulentus. The Prionotropis

woolgari listed from this zone was wrongly identified. (168). Discussion of the faunal zones of the Blairmore region was made by McLearn (104) in 1929. The possibility of a zone with "Acanthoceras" in the base of the Kaskapau shale was suggested by Warren (158) in 1930. Webb and Hertlein (169) in 1934 published a regional paper on the Alberta shale in which they stressed the importance of an "Acanthoceras" zone, and in which they stated that Priootropis occurs only within the range of the Inoceramus labiatus zone and therefore does not constitute a zone in itself.

In 1937 McLearn (112) assigned four zones to the Alberta shale. These in ascending order were: the Watinoceras, Prionotropis, Scaphites ventricosus, and Baculites ovatus zones. Below the Watinoceras zone he listed "Acanthoceras" faunas. At this time he pointed out the relationships, as far as they were known, of the Inocerami and the ammonoid species. He stated: "The exact range of each species relative to the range of other species of Inoceramus, however, has not yet been fully determined, nor has the exact range of each species of Inoceramus relative to the range of each ammonoid species been completely worked out. There is evidence, however, to show that zoning by Inoceramus does not everywhere coincide with zoning by ammonoids." (112,p.119). Warren and Stelck (168) in 1940 stated that the "Acanthoceras" type is not a true Acanthoceras and introduced the name Dunveganoceras in its place. It is here suggested that the zone formerly

designated "Barren" may now be assigned the diagnostic appellation Dunveganoceras zone.

Important Elements of the Faunal Zones:

a. Dunveganoceras zone

Dunveganoceras albertense (Warren), Dunveganoceras poucecoupense Warren and Stelck

b. Watinoceras zone

Watinoceras cf. coloradoense (Henderson), Inoceramus labiatus Schlotheim

c. Prionotropis zone

Prionotropis woolgari, Prionotropis caurinus McLearn, Prionotropis hyatti Stanton

d. Scaphites ventricosus zone

Scaphites ventricosus M. & H., Scaphites vermiformis M. & H., Baculites asper Morton, Baculites cf. anceps Lamarck, Inoceramus umbonatus M. & H., Inoceramus pontoni McLearn, Cardium pauperculum Meek.

e. Baculites ovatus zone

Baculites ovatus Say, Desmoscaphites bassleri Reeside, Scaphites leei Reeside, Inoceramus lundbreckensis McLearn, Pteria linguiformis E. & S., Tancredia americana M. &. H.

Range and Distribution of the Faunal Zones:

a. Dunveganoceras zone: The fauna of this zone is known to occur in the uppermost beds of the Dunvegan sandstone and the basal beds of the Smoky River shale in

the region of the Peace and Smoky rivers (100), (168), near the base of the Blackstone member near Luscar (158), and in the basal Alberta shale on Castle river (169). From this latter area the species Acanthoceras (Dunveganoceras) albertense was collected by Webb. In terms of the standard European chronology this fauna is of Cenomanian age.

b. Watinoceras zone: The Watinoceras fauna has been reported from near the base of the Kaskapau member on Smoky river (112), from the middle of the Blackstone member at Mountain Park, and from beds about 200 feet above the base of the Alberta shale on the Elbow river (156). The fauna has also been collected on Tuskoola mountain (112, p. 115), on Pine river (112), on Stinking creek in the Wapiti river basin (37), and on Mill creek (104, p. 93). The age of this fauna is Lower Turonian.

c. Prionotropis zone: Fauna of the Prionotropis zone have been reported from the Kaskapau (100), (112), in the uppermost beds of the Blackstone (156), (112), and from the Lower Alberta shale (102), (112), (169). The Prionotropis fauna is of Upper Turonian age.

d. Scaphites ventricosus zone: Warren and Rutherford (156) in 1928 stated that, as a rule, Scaphites occurs just above the Cardium sandstone and has been found to within 300 feet of the top of the Wapiabi or Upper Alberta shale.

Webb and Hertlein (169, p. 1405) mention the occurrence of Scaphites ventricosus from beds in the lower part of the Cardium member.

"Scaphites ventricosus Meek and Hayden occurs above the beds with Prionotropis in the Alberta shale of southwestern Alberta, in the Cardium sandstone and lower part of the Upper Alberta shale of the Sheep Creek, Bragg Creek and adjacent areas, in the lower part of the Wapiabi shale of the Mountain Park area, in the Badheart sandstone and base of the upper shale member of the Smoky River formation on Smoky River....." (112, p. 116). Previously McLearn (96), (100), (102), (104), had reported this fauna as also occurring in the uppermost beds of the Kaskapau member.

The Scaphites ventricosus fauna is uppermost Colorado in age and is referrable to the Emscherian (Coniacian) of the European nomenclature (162). Reeside (100), (104), would extend its range to include Lower Santonian.

e. Baculites ovatus zone: Warren and Rutherford (156) stated that the Baculites ovatus zone occurs in the uppermost 200 to 300 feet of the Alberta shale and in places has been found in the lowermost beds of the overlying sandstones. Webb and Hertlein (169) record this fauna in the central and northern foothills from about 600 feet below the top of the Wapiabi to within a few feet of the Wapiabi-Belly River contact. "The Baculites ovatus zone apparently includes the upper part of the

Wapiabi in the Mountain Park area, part or all of the Upper Smoky River shale on Smoky river....." (112, p. 117).

Baculites ovatus itself is absent in the southern foothills but McLearn (112) considers Inoceramus lundbreckensis McLearn as diagnostic of this fauna. For the most part the range of Inoceramus lundbreckensis McLearn corresponds to that of Baculites ovatus, but in some places it is reported to extend down into the ammonoid zone of Scaphites ventricosus. The Baculites ovatus fauna is Montana in age and represents the Santonian (Lower Senonian) of the European sections.

8. Uppermost Cretaceous

Introduction

In the foothills areas the various formations of the uppermost Cretaceous as recognized on the plains, are not readily differentiated. In most cases the marine shale formations which divide the continental beds of the plains did not reach as far west as the foothills. For this reason all the freshwater deposits of the area above the Alberta shale have in most cases been grouped into a single formation. Various formational names have been assigned to this thick series of continental beds by workers in different areas.

Previous Work

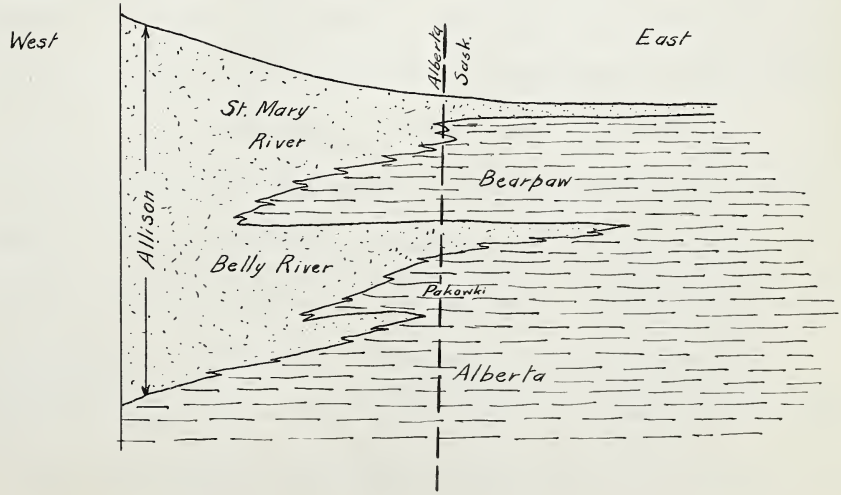
In southern Alberta the Cretaceous above the Alberta shale has been referred to as the Allison formation (63), (91), (123), (125), (126), (102), (104), (60), (12), in the western foothills, and the Belly River, Bearpaw and St. Mary River formation (151), (80), (131), (180), in the eastern foothills region. Some writers have used the term Allison as the equivalent of the Belly River formation, whereas others have used the term to imply all strata above the Alberta shale, including beds possibly of Tertiary age. Farther north, in the Turner Valley area, the terms Belly River, Bearpaw and Edmonton (16), (146), (40-54), have been employed. In west-central Alberta various names - Brazeau formation (84), (71), Saunders formation (3), (4), (132), (133), Foothills series (8) - have been used for these beds. Still farther to the northwest in the Peace river area the strata bear the appellation Wapiti (21), (88), (94), (39), (136), (177). More detailed descriptions of these formations will be rendered in the ensuing discussion.

Lithology, Distribution, Thickness

General Statement: The uppermost Cretaceous continental deposits extend throughout the foothills area from the 49th parallel to the vicinity of the Peace river. Only in the southern portions does the marine Bearpaw shale enter the sequence, and then only in the eastern foothills. The series consists of a

great thickness of freshwater sandstones and shales containing some coal seams. In the Crowsnest region MacKay (73) reported a thickness for the Allison formation of 2,500 feet in the eastern part of the pass and 4,000 feet at Coleman. From the Turner Valley area a combined thickness for the Belly River, Bearpaw and Edmonton formations of 2,850 to 3,800 feet was reported by Hume in 1939. In the Saunders creek basin Allan and Rutherford (3) reported an average thickness of 12,000 feet for the Saunders formation, whereas in the vicinity of Jasper Park a thickness of 11,000 feet was assigned to the Brazeau formation by MacKay (71). Farther north in the Wapiti river basin, 1,100 feet of beds, representing only the part exposed, have been assigned to the Wapiti formation (39).

The following diagram, matic sketch shows the characteristic wedging of the marine and continental uppermost Cretaceous formations of southern Alberta, and western Saskatchewan. Adapted from Russell (130, p.97).



Turner Valley and Adjacent Areas - The Type Section:

As the uppermost Cretaceous beds have probably received closest attention in the Turner Valley area, the writer, for this thesis has chosen this region as the type locality.

Rose (126) reported the presence in the Highwood area of the Allison and St. Mary River formations. In the Sheep river area Slipper (146) in 1921 assigned 1,900 feet of beds to the Belly River, about 100 feet to the Bearpaw, and 1,300 feet to the Edmonton. The Bearpaw, in association with the Belly River and Edmonton, was reported from the Moose Mountain area by Cairnes (16), but it has since been shown that no Bearpaw is present within the area. Later reference to these beds is found in the reports of Hume (40-54).

Belly River Formation:

The Belly River formation consists of a series of non-marine sandstones and shales. Hume (52), (54), has described the upper part of the formation as consisting of coaly shales, sandstones and coal seams, the remainder of the formation consisting largely of grey sandstones and dark green and grey shales, in part with much ironstone. About 950 to 1,000 feet above the base of the formation is a zone of massive sandstones, which, on Highwood river, contains two layers of conglomerate 140 feet apart. A Unio bed occurs 90 feet above the lower conglomerate. A thin carbonaceous shale layer with a thin coal seam about 6 inches

thick occurs about 20 feet above the base of the greenish sandstones and shales at the base of the formation. This horizon is very persistent in this area and while several feet of Belly River strata occur below it, it serves as a convenient marker to divide the Belly River from the underlying Alberta shales. This same coal seam has been seen at a comparable horizon many miles north of Bow river. Coal seams occur at the top of the Belly River formation in a series of beds that are relatively soft and bentonitic. The contact between the Belly River and the overlying Bearpaw is generally considered as the top of this coal zone, but owing to the structural complications which have involved these coal seams, and to the fact that small coal seams occur within the Bearpaw, the contact is not easily determined.

Bearpaw Formation:

As described by Hume (52), (54), the Bearpaw in the main consists of soft, grey shales alternating with some bands of hard, grey, and pink sandstones. Thin coal seams, bentonite, and in places glauconitic bands, are present. On Highwood river it carries marine fossils but it is considered to be a near-shore phase. The equivalent of the Bearpaw formation has been observed on Elbow river, but so far it has not been recognized on Bow river (54, p. 2). The thickness of the formation has been placed by Hume at 150 to 200 feet, but it may thicken to as much as 400 feet in some areas.

Edmonton Formation:

Overlying the marine Bearpaw are the continental measures of the Edmonton formation. In Turner Valley this formation has been described by Hume (52), (54). Soft sandstones with ironstones, shale and coal constitute the lower part. In most places the base of the Edmonton formation consists of soft beds containing coaly and dark carbonaceous shales with coal. These beds have generally become involved in structural deformations. In a few places, however, the base of the Edmonton is recognizable and consists of a fairly massive sandstone, in part conglomeratic, in turn followed by the coaly shale and dark shale with coal as mentioned above. Hume assigned a thickness of 150 feet to these lower beds. An oyster bed, in places more than a foot thick, composed almost entirely of oyster shells, occurs within these lower beds. The upper part of the Edmonton consists of heavy-bedded, hard sandstones alternating with shale. In places the Edmonton is highly bentonitic. Due to extensive deformation within this formation, the exact sequence of beds is difficult to obtain, and any statement of thickness needs must be but approximate. Hume (54) in 1940 reported a thickness of about 1,100 feet for the formation on Highwood river. A rapid thickening to the north occurs and the formation may be represented by 2,800 feet of beds on Bow river. (54, p. 2). The upper contact with the Tertiary Paskapoo formation is marked by a sandstone with coarse pebbles

erratically distributed as lenses in the Paskapoo. Pebbles and cobbles from 3 to 5 inches in length are present within this zone.

Crowsnest Pass and Adjacent Regions: In 1912 Leach (63) applied the term Allison Creek sandstones to a series of continental, pale greenish to yellowish, light-weathering, soft, coarse-textured sandstones lying conformably upon the Alberta shales. On McGillivray ridge 1,900 feet of beds interrupted by faulting are exposed. Similarity to the lower members of the Blairmore formation exist but, as pointed out by Leach, these Upper Cretaceous sandstones are generally lighter in color, more massive, and do not so readily disintegrate into crumbly angular fragments. Although no fossils were found he stated that the formation may possibly be equivalent in age to the Belly River series.

The term Allison (Belly River) formation was employed by MacKenzie (77) in 1913 in the South Fork coal area, for a series of sandstones and shales lying conformably upon the Alberta shale and representing the youngest bedrock of the area. Sandstones predominate and are mostly white or light grey, sometimes pale green, in color. They are rather soft, massive or with shaly structure, and often laminated and cross-bedded. Beds of dark grey, and light green plastic shales occur. The top of the formation was not observed but about 2,000 feet of beds are exposed on the west branch of the South Fork river. MacKenzie reported fossils as

being rare.

The Allison formation in the Crowsnest area was reported by Rose (123) as the stratigraphic equivalent of the Belly River sandstone of the plains. He assigned 2,500 to 3,000 feet of beds to the Allison as it is exposed beneath the overthrust older formations, but stated that this thickness probably represents the total thickness of the formation. At the base a 250- to 350- foot massive, light grey, cross-bedded, coarse-grained sandstone containing concretions and ironstone nodules, is overlain by fifty feet of grey shale with interbedded non-commercial coal seams. Above the shale are 2,000 to 2,500 feet of interbedded, grey sandstone and grey-green shale. The formation becomes very shaly towards the top and at several localities Rose reported observing black shale and a small coal seam. A conglomerate layer was noted in one locality. McLearn (91) in 1915 reported two brackish water and two freshwater faunules from this succession. The brackish water forms appear one in the basal sandstone member and one in the intermediate shale member. The two freshwater forms are from the upper sandstone member.

MacKay (73) reported that in the Crowsnest area at least two coal seams occur near the top of the Allison (Belly River) formation. He assigned a thickness of 2,500 feet for the formation in the eastern part of Crowsnest pass and 4,000 feet at Coleman. No younger Cretaceous deposits and no strata of Tertiary age occur

within the area.

Disturbed Belt of Southwestern Alberta: In the disturbed belt the occurrence of the Belly River, Bearpaw and Edmonton formations has been noted by Stewart (151). Allan and Rutherford (180) reported the presence of Belly River strata in the area east of Burmis, and Rose (125) reported the Allison formation overlain by the St. Mary River on Oyster creek, a tributary of the Oldman. The identification by Stanton of fossils from near the base of the latter formation, however, favored a Belly River age (125). Above the basal sandstone member which is typically developed, is an orderly succession of westerly dipping soft, grey sandstones and shales. Rose assigned a thickness of 10,000 feet to these upper beds and stated that the St. Mary River or possibly even younger formations may be represented towards the top. An oyster bed occurs near the base of the series.

The Belly River formation is similar lithologically to its development in the Turner Valley area. On Oldman river Stewart estimated a thickness of 3,000 feet for the formation, with a thinning toward the north and south, on Crowsnest river 2,500 feet, and on St. Mary river near the 49th parallel about 1,600 feet.

In the eastern part of the disturbed belt the Bearpaw formation is exposed on all the rivers between the St. Mary and Oldman (151). On Lee creek Stewart reported a limestone band about

1 foot thick about 200 feet above the base of the formation. Three lenses of massive buff-colored sandstone occur in the section on Oldman river. From Oldman river south the break between the continental sandstones and the massive Bearpaw shales is well marked, the transition from Belly River to Bearpaw strata being best observed on Lee creek and on Oldman river. The extension of the Bearpaw formation northward from Oldman river is observed on Willow creek, but on Pekisko creek the dark clay shales and marine fossils of the Bearpaw are absent and the horizon is represented by an alternation of sandstones, arenaceous shales and thin coal seams, a combination characteristic of the upper part of the Belly River and the lower part of the St. Mary River formations. No complete undisturbed section of the formation was observed but the entire thickness, though the formation is only partly exposed, is present on Oldman and Crowsnest rivers and on Lee creek. With due allowance made for repetition by crumpling and folding, the maximum thickness was estimated by Stewart to be about 700 feet.

Lithologically the St. Mary River formation is very similar to the Belly River formation and determination of isolated exposures is difficult. The lower part of the St. Mary River is generally more shaly and calcareous than the upper and everywhere contains coal seams and oyster beds. The sandstones are all fine-grained and often exhibit fine cross-bedding and ripple-markings. The shale is irregularly bedded and in some cases calcareous and

concretionary. An excellent horizon marker in the southern area is a bed composed almost entirely of the shells of oysters and other molluscs, which overlies the coal near the base of the formation. This oyster bed attains a thickness of 2 to 8 feet on the Belly river and almost 12 feet on Waterton river. The best sections of the formation are seen along the valleys of the St. Mary, Belly, Oldman, Waterton, Crowsnest and Castle rivers and Lee, Pincher and Indian Farm creeks. The thickness of the formation varies, Stewart having estimated 1,600 feet for the section on St. Mary river, 2,700 feet on Crowsnest river and 3,000 feet on Oldman river. The upper contact of the St. Mary River formation with the overlying Tertiary deposits is generally difficult to draw, there being a continuation of continental sandstone beds into the overlying formations. Where the Tertiary Willow Creek formation overlies the St. Mary River the contact is drawn on a lithologic basis, as the Willow Creek formation generally exhibits a characteristic red color.

Southern West-Central Alberta: In the following discussion southern west-central Alberta is considered to extend from the Bow river northwestwards to the North Saskatchewan river in the Brazeau area.

In the Bow river area Rutherford (134) reported the Belly River and Edmonton-Paskapoo beds as being lithologically

similar to the development of these strata in the Turner Valley area. He was unable, however, to differentiate between the Edmonton and Paskapoo, for the succession is one of apparent continuous deposition of freshwater beds. Rutherford estimated the thickness of the Belly River to be 2,500 feet in the eastern part of the area and over 3,000 feet in the western part, and that of the Edmonton-Paskapoo as 3,500 feet. The upper part of the Paskapoo and any younger strata that may have been present have been eroded off.

The Belly River and Edmonton have been described from the Wildcat Hills area (48), (40), but the Bearpaw does not extend north of the Bow river in the foothills of Alberta. The Belly River and Edmonton formations do not differ markedly from their development in Turner Valley. At various horizons in the Belly River lenticular beds of black chert and grey quartzite pebbles are found in the coarse sandstone. Hume (48) reported that in some areas a conglomeratic sandstone horizon as much as 4 feet thick occurs close to the base of the Belly River beds. Generally speaking, the upper part of the formation is more shaly, is softer, is lighter in color, and is more bentonitic than the lower part. On Little Red Deer river a small coal seam 15 inches thick occurs 30 feet above the base of the formation and may represent the coal occurring at the base of the Belly River formation in the Turner

Valley area. Another seam, 1 foot thick and of poor grade lignite, occurs on Little Red Deer river 250 feet below the contact with the Edmonton formation. Hage reported the thickness of the formation on Little Red Deer river as 2,600 feet, with a thickening to the north and from east to west.

In the Wildcat Hills area bentonite in association with reddish-brown ironstone nodules is common in the Edmonton. In places this bentonitic material forms a white coating on outcrops. On the whole the sandstone beds of the Edmonton are finer grained and softer than the Belly River sandstones. In this area, the basal bed of the Edmonton formation is a coarse-grained sandstone approximately 90 feet thick. In the basal 10 feet several bands consisting of pebbles ranging from $\frac{1}{2}$ inch to $9\frac{1}{2}$ inches in length exist. These pebbles consist predominantly of quartzites of various colors, with chert, porphyry, quartz and sandstone pebbles in minor amounts. Hume contended that these pebbles had their source to the west in the Selkirks. This basal conglomerate is well exposed on Little Red Deer river and according to Hume is not known to occur south of Bow river. The conglomerate suggests a break in sedimentation during at least part of the time when the marine Bearpaw formation was being deposited in the areas to the south and east. Commercial coal seams were not observed within the area. Hage reported a probable thickness of the Edmonton formation in this area of 3,000 feet. The Edmonton is overlain

conformably by the Paskapoo formation of Paleocene age, the base of which is marked by a massive sandstone bed (40, p. 4).

MacKay (76) reported a similar development of the Belly River and Edmonton formations in the Fallentimber area. In this region, however, at least two 3- to 6-foot thick coal seams are present in the Edmonton. The base of the formation is marked by a bed of conglomerate that ranges up to 1½ feet in thickness and is composed of chert pebbles of various colors, quartz, and shale fragments. This conglomerate bed corresponds to the one reported from the Wildcat Hills area. Slabs of silicified wood and bone fragments of a duck-bill dinosaur were found in the conglomerate on Red Deer river. Because of faulting and the presence of a heavy overburden of glacial drift, accurate determinations of the thickness of the formations were not possible. MacKay reported a thickness of 3,600 feet of Belly River strata on Red Deer and Little Red rivers and Frozenman creek, whereas to the west on Fallentimber and Grease creeks the formation is represented by at least 3,900 feet of strata. He estimated a thickness of 3,000 feet for the Edmonton.

In the area between the Bow and North Saskatchewan rivers Evans (38) was unable to differentiate the Belly River and Edmonton formations. Coal seams are present in his sections. He reported a combined thickness of 8,063 feet for the strata of

these two formations.

West-Central Alberta: West-central Alberta is here considered to extend from the North Saskatchewan river in the Brazeau area to the Athabaska.

In the Bighorn basin Malloch (84) introduced the term Brazeau formation for a series of alternating beds of black and brown shale with greenish grey sandstones containing chert pebbles. He assigned 1,680 feet of strata to the formation but stated that the upper part of the formation had been eroded off. Malloch's Brazeau formation corresponds to the Belly River sandstone of the plains (8, p. 34).

In 1923 Allan and Rutherford (3) introduced into the literature a new term - Saunders group - for the thick series of continental deposits above the Wapiabi shales in the Saunders creek coal basin. At this time they subdivided the Saunders group into three parts, Upper Saunders formation and Lower Saunders formation separated by the Saunders coal series. This term implied the equivalent of the Belly River, Bearpaw, Edmonton and perhaps some Paskapoo, and is represented by an approximate 12,000 feet of sediments. In the continuation of their work in the following year, this subdivision of the series into parts was dropped, for it was found not to have regional applications. The term Saunders formation was then employed to include all these strata.

In 1934 Allan and Rutherford (8) proposed the term

Foothills series for all strata above the Upper Cretaceous marine beds in the foothills. This term has the same general application as the term Saunders formation and was introduced with a view to its use in a regional significance to supplant all former terms applied to these strata throughout the foothills region. The lithology of the formation varies in no marked degree from the development of these strata in the Turner Valley area. "Special types of sedimentary beds, such as those composed almost entirely of volcanic dust, form local horizon markers, but these have not been found to have a wide areal distribution"(8, p. 35). The formation shows no marked stratigraphic or lithologic breaks and thus the placing of the Belly River - Edmonton and Edmonton - Paskapoo boundaries is attended with great difficulty and, in most cases, has been dispensed with. The lower part of the series is the approximate stratigraphic equivalent of the Belly River formation on the plains.

In the Brazeau area Sanderson (139) in 1939 was unable to establish the Belly River - Edmonton contact and the upper boundary of the Edmonton. He estimated the thickness of the Belly River - Edmonton on Brown creek as about 5,150 feet, and the thickness of the Saunders on Chungo creek as 6,700 feet.

In the area between the McLeod and Athabaska rivers (132) a distinction between the upper strata of the formation and the

beds near the base of the formation is noticeable. Rutherford reported that in general the upper beds are softer, not so well consolidated, and are more often of a yellowish to brownish color, whereas the basal beds, especially the sandstones, are usually light grey or greenish grey in color. In this area a massive conglomerate bed 75 feet thick occurs about 665 feet above the base of the formation. To the southeast on Pembina river this conglomerate becomes more arenaceous, while still farther to the southeast on Blackstone river, it is more of a pebbly sandstone than a true conglomerate, with the pebbles occurring as lenses in a well cross-bedded sandstone. Northwest of the McLeod river several conglomerates occur in the basal Saunders beds, such conglomerates being well exposed on the north side of Athabaska river opposite the mouth of Prairie creek. In almost all of these conglomerates the pebbles are seldom over 2 inches in diameter and generally less than one inch. Frequent lenses or rows of quartzite pebbles that have diameters as great as 12 inches, and averaging about 6 inches, occur at different horizons higher up in the formation. Such occurrences are generally local having but a small lateral or vertical extent. In all of these areas between the Blackstone and Athabaska rivers as reported on by Allan and Rutherford, a thickness of 11,000 to 13,000 feet has been assigned by them to the Saunders formation.

MacKay (71) in the vicinity of Jasper Park in 1930, extended Malloch's term Brazeau formation to include all strata comparable to the strata of the Saunders formation. He described the formation as consisting of freshwater, soft, grey, cross-bedded, green and brown weathering sandstones and greenish-grey shales with several massive beds of conglomerate composed of small chert and quartzite pebbles. About 8,000 feet above the base one volcanic-ash bed and several important coal horizons were observed. To this formation MacKay assigned a thickness of 11,000 feet.

Northern West-Central Alberta: Northern west-central Alberta is here considered to extend from the Wapiti river basin to the Peace river.

In this area the stratigraphic equivalent of the fresh-water deposits of the uppermost Cretaceous of the central and southern areas is the Wapiti formation. In 1893 McConnell (88) referred the Wapiti River sandstones on Peace river to a Laramie age. McLearn (94) in 1919 employed the term Wapiti formation and described the strata as they are exposed in the Smoky and Peace river areas. In his section, in which 900 feet of thick, massive, cross-bedded sandstones and grey to dark carbonaceous shales are exposed, he reported the occurrence of two coal horizons, one a 3-inch to 4-inch bed 180 feet above the base, the other a

4-inch bed 580 feet above the base. Rootlets, and in some places, flat concretions, occur within the formation.

The Wapiti formation was described from the Wapiti river basin in 1930 by Evans and Caley (39). In this area the entire formation is not exposed, 1,100 feet being estimated for the part which outcrops. It consists of sandstone and shale and coal seams. The sandstone, light grey on fracture and medium to coarse in grain, is frequently cross-bedded and contains bone fragments. Along the Wapiti river it weathers to a cream color and in many places weathers out in a pillar-like structure. The shale, mainly greenish-grey in color, shows little evidence of bedding and crumbles easily on weathering. Two thin seams of coal varying in thickness from 18 inches to 4 feet are present.

Rutherford (136) in 1930 reported the Wapiti as best exposed along the Smoky valley south from the Bad Heart, and in the tributary valleys along this part of the river. It underlies many of the uplands and is believed to be in part responsible for these physiographic features. It is the youngest formation in the area and has weathered into typical badland erosional forms. Rutherford described the formation as consisting of fresh-water sandstones and shales. All gradations between these two facies exist. The units vary in thickness from a few inches up to as much as 50 feet, with 10 to 20 feet being more common.

Cross-bedding, and concretionary masses in eroded faces, occur frequently in the more massive sandstones, The sandstones are generally light grey to buff in color and in the main of fine-grained texture. Poor stratification exists in the shales. A division into definite lithologic units is not yet possible. The lower 150 to 200 feet, predominantly argillaceous in character, consist of compact, poorly stratified clay shales that weather to variegated colors. Clay ironstone nodules in thin bands are common in these shales. Rutherford reported the presence of a thin coal seam, varying in thickness from a few inches up to 2 feet, in these lower beds. It is too thin however, to be economically exploited. He also reported the occurrence on Red Willow river south of Beaverlodge of some seams of commercial thickness at a horizon stratigraphically higher than the Wapiti of this area.

Capping Table Mountain and preserving it from erosion is a bed of 390 feet of sandstone, which Williams and Bocock (177) have assigned to the Wapiti formation. The contact here with the underlying Smoky River formation is indefinite, and has been placed at the base of a 50 foot stratum of even-bedded, creamy sandstone. Overlying the basal sandstone is a 50-foot bed of thin shaly sandstone, in turn overlain by 290 feet of massive, brown, red-weathering sandstone cut by vertical joints. Fucoidal

forms up to 3/4 inches in diameter are present in the upper sandstones. The narrow north-south crest of Bear mountain is capped by about 60 feet of nearly flat-lying massive sandstones containing lenses of coarse grit. Dark grey, black, green, and white quartz and chert pebbles generally less than 3/4 inches in diameter comprise this grit. This massive sandstone and grit formation is considered the probable equivalent of the capping sandstone of Table mountain.

The lower Wapiti formation is considered the stratigraphic equivalent of the Belly River formation in the plains and foothills of southern Alberta. In the Peace River district the Wapiti formation is underlain by about the same thickness of shales of Montana age as is the Belly River and its equivalents throughout the foothills of Alberta south of the Athabaska. The upper part of the Wapiti has been correlated with the Edmonton on a lithologic basis (136), (8). The Wapiti formation is thus considered the stratigraphic equivalent of at least the Belly River and Edmonton formations.

Warren stated: "The occurrence of Desmoscaphites bassleri and Baculites ovatus in the upper member of the Smoky River shale leads to a correlation of the overlying Wapiti formation with the lower part of the Saunders formation of the foothills which there immediately overlies the Colorado shale beds containing a

similar fauna." (192, p. 58).

Palaeontology of the Uppermost Cretaceous

Fauna of the Belly River Formation: On the whole, the Belly River beds are remarkably free from either plant or animal remains. References to the fossil life of this formation in the foothills belt include Stewart (151), Rose (126), Rutherford (134), Allan and Rutherford (180), and Hume (48), (52). Pelecypods, small freshwater gastropods, dinosaur bones and leaf impressions have been found. The fauna includes Ostrea glabra, Unio consuetus, Goniobasis judithensis, and the dinosaur Laosaurus minimus.

Fauna of the Bearpaw Formation: Reference has been made to the reports of Stewart (151), Slipper (146), and Hume (52) for the fauna of the Bearpaw formation of the thesis area. Landes (60, pp. 200-201) has given a nearly complete list of the Bearpaw fauna. Important elements of this fauna include Baculites compressus Say, Placenticeras intercalare M. & H., Placenticeras whitfieldi, Arctica ovata (M. & H.), Ostrea patina and Inoceramus barabini.

Fauna of the St. Mary River and Edmonton Formations: For the fauna of these formations in the area under discussion reference has been made to the following reports: Cairnes (16), Stewart (151), Slipper (146), Rutherford (134), Evans (38), Hume (48), (52), and Hage (40).

Included in the fauna are the following species: Unio danae, Ostrea glabra, Ostrea subtrigonalis, Corbicula occidentalis, Anomia perstrigosa, Melania wyomingensis, Viviparus sp., and Campeloma limnaeiforme, none of which are diagnostic.

Bones of the vertebrates Champsosaurus and Hypacrosaurus have also been collected from the Edmonton formation (40, p. 4).

Fauna and Flora of the Allison Formation: The life of the Allison formation has been discussed by McLearn (91), (102), (104), and by Berry (12). McLearn (104, p. 98) listed three fauna and a flora in descending order as follows:

Unio danae fauna (freshwater) including Unio danae M. & H., and Sphaerium planum M. & H.

Zamites albertensis flora

Corbula cf. perundata fauna (brackish)

Inoceramus cf. lundbreckensis fauna (marine)

The Inoceramus cf. lundbreckensis fauna (104, p.95-96) is a depauperate one, and occurs at levels of 100 and 185 feet above the base of the section as exposed on Gulch creek. The species I. cf. lundbreckensis itself occurs at the 100-foot level.

The Corbula fauna (104, p. 96) occurs in the lower coal zone of the Allison formation. In a 4-foot bed of grey and bluish shale at about 315 feet above the base of the exposed section on Gulch creek, a mixed or brackish fauna with Modiolus, Corbula, and Melania was found. This brackish fauna forms the transition from

the marine fauna below to the entirely freshwater fauna of the upper Allison above.

The Zamites albertensis flora (104, p. 96) occurs stratigraphically near the Corbula fauna in the lower coal zone of the Allison formation. Berry (12, p. 67) stated that a study of the flora seemed to indicate that its palaeobotanical relations are with the older rather than with the younger formations of the Montana group. Included in this flora are Zamites albertensis Berry, Sequoia heterophylla Velenovsky, Brachyphyllum macrocarpum Newberry and Geinitzia formosa Heer. Of these, all have outside affinities but the Zamites.

Also included in the Unio danae fauna (104, p. 97) are indeterminate species of Planorbis, Viviparus and Physa. Two facies, a stream or lake facies in sandstone with Unio danae, and a pond or quiet stream facies in shale with Physa and Sphaerium, are present. Sequoia heterophylla Velen? was reported at 1,725 feet above the base of the exposed section.

Fauna and Flora of the Saunders Formation: The fossil plants Sequoia heterophylla Velen., Androvettia sp.? and Cycadocarpus collected from the lower part of the Saunders formation, were identified by Berry (3, p. 54). From the upper part of the formation, Berry (3, p. 55) determined the fossil plants Pinus sp., Arundo groenlandica Heer? and Platanus sp. Invertebrates present include Unio, Campeloma, Viviparus and Goniobasis (3, p. 55).

McEvoy (89, p. 26) in 1899 recorded the following fossils from the Athabaska river area: Physea copei, Patula sp. and Zamites or Conulus, as occuring in beds equivalent to the Edmonton formation.

Fauna of the Wapiti Formation: No invertebrate faunas have as yet been collected from the Wapiti, but a few fragmentary vertebrate bones, probably dinosaurian, representing the most northerly known occurrence of such in Upper Cretaceous beds, have been reported (136, p. 31).

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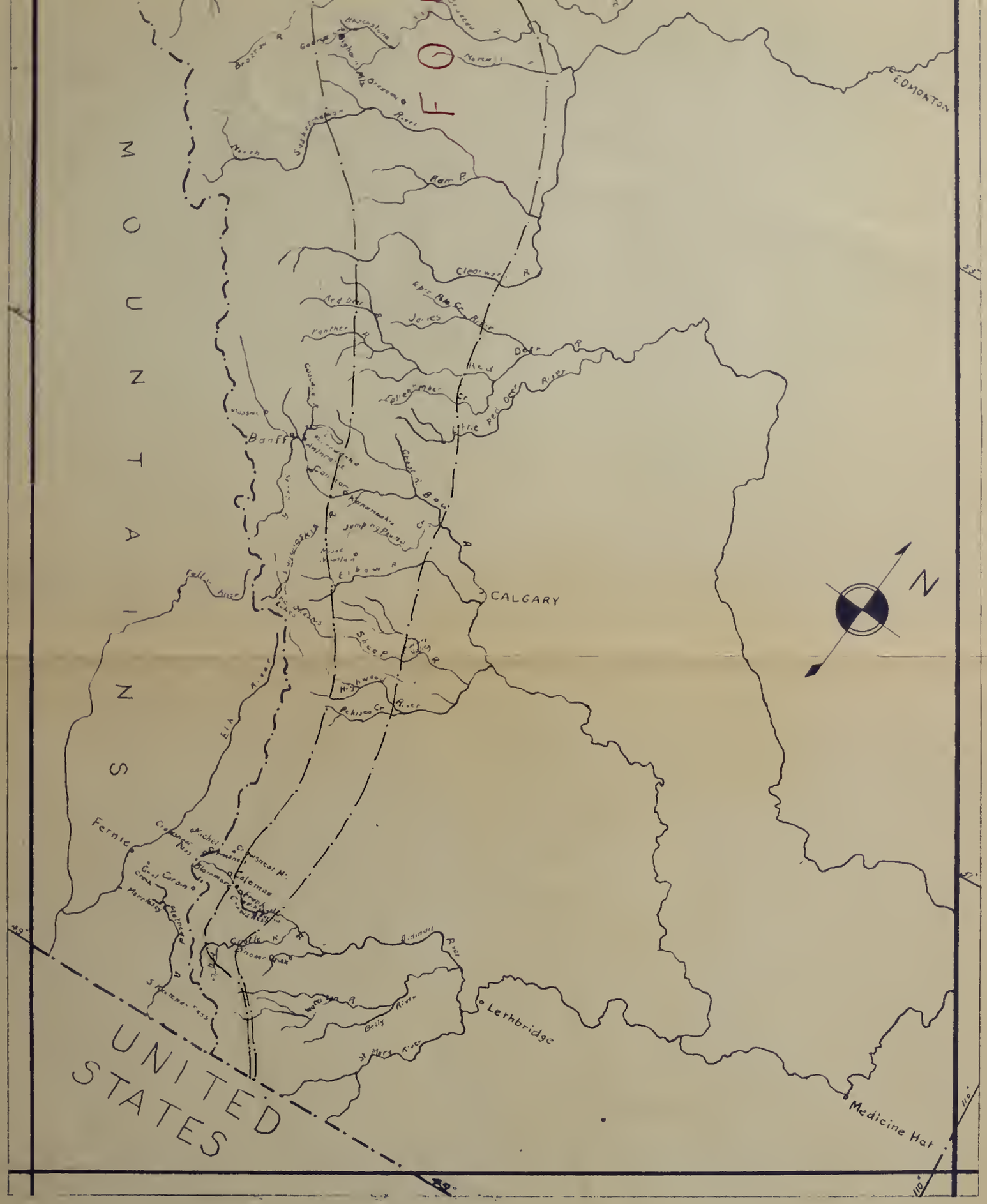
MAP
OF
FOOTHILLS REGION
OF
ALBERTA
Scale 1 inch = 35 miles
April, 1941
PEACE RIVER
BLOCK
PEACE
RIVER
Peace River
BRITISH COLUMBIA
ALBERTA
Kiskatinaw R
Wapiti
Wapiti River
Grande Prairie
Smoky River
Smoky
Little Smoky River
Lesser Slave Lake
Bellard R
River
Athabaska
McLeod R
McLeod River
Embarras R
Pembina River
Brazeau R
Nordegg R
Saskatchewan River
North
Ram R
EDMONTON
ROCKY
FOOTHILLS



Map to accompany thesis by H. Kunst, 1941.

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